EARLY CONTRACTOR INVOLVEMENT AND THE TEAM APPROACH

By

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EARLY CONTRACTOR INVOVEMENT IN COMMERCIAL DEVELOPMENT

by

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Submitted to the Department Architecture and Planning on September 8, 1989 in partial fulfillment of the requirements for the Degree of Master of Science in Real Estate Development

ABSTRACT

Early contractor involvement in the project team during the design process can have important cost, schedule and budget control benefits. A team approach is one manner to integrate the contractor's construction expertise into the design process. Moreover, this strategy is most appropriate when the expected benefits of early contractor involvement are greater than the costs associated with its use.

This thesis focuses on the early involvement of the contractor in the project team and the team approach. It looks at how the contractor is able to influence the design process as well as strategies owners might adopt to achieve those benefits. A review of the literature indicates that early contractor involvement has important cost, schedule and budget control benefits. A single in-depth example of early contractor involvement in design illustrates how the contractor is able to influence the design process under a team approach. Finally, several examples from industry indicate that some commercial developers have adopted a strategy of early contractor involvement. From this research, a model is developed to describe various strategies owners may have for using early contractor involvement and the team approach. This model indicates that when the potential for savings during the design process are great, early contractor involvement seems most appropriate

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Introduction

"While the traditional 'Hard-Bid' approach to building construction remains effective and cost-efficient, the 'team approach' is grabbing an increasing share of the private market." (Greenhut 1989).

This quote indicates that changes are occurring in the ways the project team is structured. This thesis attempts to examine this change, the use of the team approach as a means to achieve the contractor's early involvement in the design process, and to propose a model for evaluating when use of this strategy is most appropriate.

The thesis is divided into four parts: a literature review section, a section providing an in-depth example of contractor involvement, a section that surveys industry practice of project team structure and contractor involvement, and a final section that develops a model for understanding strategies for early contractor involvement.

Part I reviews the literature relating to early contractor involvement. This research concludes that the primary benefits for the owner of early contractor involvement in the design process are construction cost savings, construction time savings, and greater control over construction cost through design. Part II is an in-depth example of one decision during the design of a office building. This

example illustrates how one of the benefits explained in the literature actually accrues to the owner. Part III is a survey of how several commercial development companies chose to involve the contractor in the project team. Part IV, the final section, synthesizes the information on the benefits of early contractor involvement and how they occur with the information gathered on the industry practices of contractor involvement in project team. A model for owners to use when evaluating the benefits of early contractor is developed to provide a framework for understanding when use of a team approach is most appropriate.

Part I. Literature on Early Contractor Involvement in the Project Team

The literature on early contractor involvement can be divided into two general groups, which will be described in order below. The first group of studies are more general and deal with early contractor involvement in the project team. These studies suggests that early contractor involvement may improve the design process. The second group of studies are more specific. These studies focuses on various aspects of teamwork within the project team of owner, architect, and contractor. Among this second group of articles are several articles in trade publications that describe the benefits of a "team approach" as improved budget control during the design phase. Other studies in this second group suggest that both early contractor involvement and teamwork in the project team can improve trust and communication between the members of the project team. Still other articles on liability, however, indicate that early contractor involvement also changes the assignment of risk between the parties and may increase the liability exposure of a contractor. Many of these studies cite benefits that occur during the construction phase or in the implementation of a design, but a careful investigation of these benefits is beyond the scope of this thesis.

Group I. Improving Construction Value Through Early Contractor Involvement

There are three principal studies that recommend early contractor involvement in project design. The Business Roundtable produced a study (BRT 1983). that attempted to analyze the decline in productivity of the entire construction industry and make recommendations for corrective action. The American Society for Civil Engineers conducted a workshop in 1983 on improving quality in the construction industry and later produced a professional practice manual (1988) to assist in informing others of the workshop's conclusions. The final study, from the department of civil engineering at Stanford, was entitled "Constructability Improvement During Conceptual Planning." These studies all recommend that construction expertise be integrated into the design process early. One benefit of these recommendations was said to be improved team communication and coordination, and the fostering of an attitude of contributing to the betterment of the team. The chief benefits, however, were viewed as improvements in what the reports call "constructability" and the "value engineering" of the project. This section first defines these terms and then discusses each of the reports in detail.

Constructability

The Construction Industry Institute's (CII) Task Force on Constructability defines constructability as "the optimal integration of construction knowledge and experience in planning, engineering, procurement, and field operations to

achieve overall project objectives" (Jortberg 1984). There are many other definitions in the literature for constructability. Bryson (1984) describes a constructability program as "the planned interaction of construction with project definition and design for the purpose of assessing all factors that affect design and contribute to project cost and schedule." Wilson (1984) defines constructability as "analyzing each engineering activity for its impact on engineering cost, construction costs, and project schedule prior to producing drawings and, when required, a cost analysis of alternatives to define the lowest total installed cost."

For the purpose of this thesis, constructability is defined as the use of construction knowledge during the design phase of development to make the building easy to build. This construction knowledge is used to modify the design of the project and its construction schedule in ways that will make the project less prone to delays due to construction difficulties or less risky while not adversely affecting the owner's other objectives. These objectives might include quality or minimizing total project cost. Constructability may increase labor and material cost of construction in order to reduce the time of construction. Shortening the length of the entire construction process can result in very large savings in terms of reduced interest costs on the

construction loan as well as other benefits such as decreased labor from less hours spent on construction.

An example of constructability would be the recommendation by the contractor to change the sequence of construction. Given the owner's objective of an early building occupancy, the contractor might suggest building the roof earlier than planned on a project to help weather proofing during the winter months. This would result in the project being less susceptible to construction problems due to poor weather and allow construction to continue without delays during seasons with adverse conditions. This action may initially increase project costs, but could reduce weather protection cost during construction and, more importantly, reduce the risk of not meeting the owner's objectives on schedule.

Value engineering

The Construction Management Committee defines value engineering as "an organized creative approach which has for its purpose the efficient, systematic identification of potential cost savings and the elimination of unnecessary cost. Value engineering has the greatest effect on savings during the pre-construction phase. It includes operability and maintainability; a higher investment cost may be prudent when evaluated against future operating costs" (Construction Management Committee 1987). This definition implies, for example, the substitution of one construction material for

another. Substituting a less expensive facade but keeping the overall project appearance would be an example of value engineering.

Related terms include value management and life-cycle costing. Value management attempts to reduce initial project costs without affecting project quality. Life-cycle costing is concerned with evaluating a purchase in relation to total lifetime costs, the initial purchase price plus the cost to maintain and operate over the life of the product.

In this thesis value engineering is defined as minimizing a building's construction costs while not noticeably affecting its quality. An example would be if the architect originally specified a masonry exterior, but the contractor was able to suggest a less costly alternative such as precast panels faced with brick tiles. This suggestion would not significantly affect the the aesthetics of the project and could save substantial amounts of money.

The important point that relates to early contractor involvement is that the owner's overall project objectives are better served through both constructability and value engineering and this is made possible by reducing construction time, risks of construction delays, and construction costs.

Measuring the Benefits of Constructability and Value Engineering

Constructability improvement and value engineering have their greatest effect during the design phases of a project (Paulson 1976). However, it is difficult to quantify the benefits of these activities. This is due in part to the fact that the costs of the alternative approach cannot be compared directly with another approach.

Substituting a construction technique might reduce budget projections: however, during construction, the actual implementation may be more expensive. Since the original design remains untested, it is impossible to know whether it might have encountered other problems as well. Therefore, while projected cost savings might be possible, an accurate and definitive estimate of true cost savings from constructability may be impossible.

The benefits of value engineering are also difficult to quantify for the same reasons. The actual implementation of changes may be more expensive or time consuming than anticipated, but the original untested design could have encountered other problems during construction. In addition, developers and contractors interviewed for this thesis indicated that project savings in one area were often spent in another to improve quality. One developer stated "we know how much a quality building should cost. If after value

engineering the price is below $80 a foot then we know we have cut too much and we have to put money back into the project." Thus, the benefits of value engineering may not be always result in a reduction of project cost but result in the less tangible benefits of improved building quality.

There is no generally agreed upon way to measure the benefits of constructability or value engineering. Most studies, however, focus on the savings in time and costs from the original projected budgets.

The Three Reports

The Business Roundtable Construction Industry Cost Effectiveness Project Report (BRT 1983) studied ways to decrease the cost of new building construction in the United States and identified several opportunities. One of the recommendations focused on improving constructability by integrating construction expertise into design and engineering. The report discusses specific benefits of early contractor involvement in the design process, including "cost and schedule reduction by optimizing the design and construction relationship; optimizing design details and sequence to meet construction's needs; incorporating the latest appropriate construction technology into the design; developing work-simplifying methods; and minimizing labor intensive designs." (BRT 1983, p.1).

The BRT B-1 study team reported that the effective integration of construction knowledge in design requires that construction experts participate in conceptual development and planning for the project, in making decisions, in design reviews, and in scheduling and cost estimation. However, it also noted that there were obstacles that hinder integration, such as resistance by owners because of perceived extra costs, and the reluctance of architects and engineers to accept input from construction personnel.

The Business Roundtable study estimated a return of 10 to 20 times the dollar amount invested in improving constructability in the design of a project. Moreover, it cited examples such as hiring a full time constructability consultant for $32,000 which enabled a design team to reduce the planned budget by $540,000 (BRT 1983, p.57). However, the BRT report goes on to reconfirm that it is very difficult to quantify these savings from constructability because, as discussed above, the costs of the alternative approach cannot be known.

Finally, the BRT made action recommendations, key among them: "Write contracts that give contractors an incentive to mesh engineering and construction expertise with the process called 'constructability'" and cited the potential for this cost savings (BRT 1983).

The American Society of Civil Engineers (ASCE) published a professional practice manual titled "Quality in the Constructed Project" (1988) in response to a recognized need to prevent failures and improve construction industry quality. The manual made several recommendations related to improving construction quality including recommendations for multi-disciplinary design reviews for projects and incorporating constructability reviews in at least two points during the project design. The publication also stressed the importance of good teamwork.

The ASCE asserts that "The major participants (owner, design professional, and constructor) are, or should be, involved in nearly all phases of a constructed project..... When the three members of the project team are competent and work together, quality in the constructed project is likely to be achieved." (ASCE 1988, p.2).

The manual also makes two important recommendations for project owners. First, the owner should establish complete and realistic requirements and objectives for the project; second, the owner should provide a thorough understanding of the roles and responsibilities of each member to the owner and to each other. "Clearly communicating information such as requirements, expectations, scope, cost, schedules, and technical date is a vital element to introducing quality in the constructed project. Coordination requires effective and

frequent communication among the project team members." (ASCE 1988).

The workshop, on which the publication was based, further elaborated the keys to improving quality in construction. Miller (Fox 1983, p.44). suggests that as projects become more complex and time-intensive, no one individual can assure quality throughout the project and that the individual involvement must be replaced by a team approach. He outlines a team approach to design as: 1) development of a plan, 2) assignment of roles, and responsibilities, 3) establishment of performance standards, 4) setting up a system of rewards that reinforces performance, and 5) providing effective communication.

Miller clearly states that teamwork in design requires that representatives of the owner and the contractor must be brought into the design team to provide continuity of design quality throughout the project. Not including the owner and contractors in design teamwork frequently results in misunderstandings and extra cost in the final design. "It is mandatory that the maximum amount of interfacing between owner, designer, and contractor take place during the development of a design in order to minimize insufficiency of bid documents." (Miller 1983).

He states that without this contact between owner, architect, and contractor, designs may be developed that are not constructible. Specifically, implementation of the designs in the construction process may causes unnecessary difficulties for the builders which in turn causes increased bid prices or costs during construction to correct or modify the original design.

Mast (Fox 1983, p.61) suggests incorporation of constructability reviews in at least two points during the design. Review by contractors during the conceptual phases of a project was considered to be of as much importance to a successful design as review in the pre-final project design phase. Mast suggests "that the design team should incorporate as much construction know-how into its documents as possible at every development stage" (Mast 1983). He also suggests that integration of contractors as part of the design team will enhance their own pride in the product hopefully leading to greater concern for project quality.

A Stanford study titled "Constructability Improvement During Conceptual Planning" (Tatum, Vanegas, and Williams 1985) states that effective integration of design and construction offers important benefits and means to achieve project objectives. The study examined 15 industrial and office buildings to determine how owners attempted to improve constructability. The study, which focused on those owners

that had initiated a constructability program, found that owners generally insisted on early involvement of experienced and team-playing construction personnel. They made constructability a high priority and found designers who were receptive to the process.

Paulson (1976) argues that increasing the integration of construction expertise into the design process is effective because decisions which are made early in the project, despite the low levels of expenditure at that time, have the highest influence on total cost. This is because project design is more flexible at the early stages. As the design progress continues decisions made earlier limit the choices and thus the ability to implement cost saving changes. By the time construction starts, changes to improve design may be very costly. The Stanford study agrees with Paulson's prescription. Indeed, the authors conclude that early construction team involvement and pre-construction planning are vital to a successful project. The Stanford study also supports the Paulson point by arguing that focusing on constructability avoids three types of problems that can result when the designer lacks knowledge of local construction factors.

The first problem is that ignorance of local construction factors may lead the designer to make design choices which are more expensive than equally acceptable alternatives which

the contractor could provide. The Stanford study gives the example of substituting concrete for steel. For a specific project, local availability of concrete and advanced contractor methods for concrete placement may make concrete less expensive for the building. Not knowing this, the designer might design a steel structure. Here the constructor, could provide "value engineering" by drawing upon his or her knowledge of local markets to suggest the change to a concrete structure

The second type of problem is that construction difficulties are increased once the project is under way. An example would be the impact of access restrictions, the inability to meet specified tolerances, the impact of erection sequences inherent in the design configuration, or the restriction of craft skills or jurisdiction.

The third and final problem is that there is an increased risk of problems from inadequate design/construction coordination or insufficient construction planning. Examples include incompatible design and construction schedules, and missed opportunities for the use of beneficial construction methods that are influenced by design.

From this the study went on to find two major types of benefit from early contractor input into the project plan: sequences and schedules that better fit construction

requirements, and design concepts and approaches which made the project easier to build. Other benefits included decreased construction scope, decreased construction difficulty, and improved construction methods and technologies. Less quantifiable benefits include team building, improved coordination of design and construction, and better construction planning.

Another focus of the Stanford study was on the elements that contribute to a successful project team. Past experience in similar projects for all members of the project team was deemed very important because it improves the ability of all members to find, communicate, and implement constructability improvements. Being a "team player" is also essential. The Stanford study describes a team player as one who adopts the project's objective and does not overly identify with the goals of a specific discipline or firm or consistently make personal advancement first priority.

The Stanford study also stated that efforts to improve coordination are also necessary for constructability improvement. Such efforts might include less formal communication, participation in meetings, free exchange of preliminary information, and other steps to lessen the natural barriers resulting from membership in different firms.

Team building, according to the study, improves both design and constructability. It establishes a rapport which will increase commitment and lessen adversarial relationships. The Stanford study further stated that the initial impetus for team building should come from the owner. The integration of the engineering and construction knowledge in the design of a project cannot be achieved by simply deciding to have integration; such integration requires providing a framework, such as an explicit team with well defined members and roles, which can work together to achieve the desired integration. Some of the managers surveyed in the Stanford study, for instance, held specific project team meetings on a quarterly or semiannual basis to identify problems and foster a team approach.

An example of this is the NYNEX real estate division. NYNEX has a procedure in which after the architect and contractor are selected for a project, the project team members along with the selected NYNEX project manager attend a three day seminar on quality. Each is asked to fill out a questionnaire that attempts to clarify what each team member expects of the other team members to achieve a quality product. The project team members then meet together to discuss what each expects of the others and a joint understanding of what quality in a project will mean is developed.

These three studies (BRT 1983, ASCE 1988, Tatum, Vanegas, and Williams 1985) suggest that project teams can better meet the owners objectives of cost, schedule, and quality by integrating the contractor early in the design process and by having the owner clearly define project goals. The most tangible benefits are in the form of cost and schedule objectives of the owner. Other benefits and improvements to the design and construction process include improved communication and coordination and more teamwork.

Group II. Articles focusing on team approach or teamwork

The majority of other articles relating to early contractor involvement focus on a particular benefit or problem area. These articles deal with the benefits of increased communication, trust, and team building. Another area of concern focuses on the increase in liability that the contractor is exposed to by greater involvement in design related activities.

Team approach and budget control

Articles (Greenhut 1989, Beard 1986, Goodspeed 1989 - trade publications of the Association of General Contractors), describe a "team approach" to design and construction in which the owner selects the architect and contractor very early in the design stages of development. Project team

members meet as a group and jointly make decisions on almost all aspects of the project design and construction.

The chief benefit to the described project team management approach is to improve constructability and value engineering, and improve budget controls. However, to be effective the team approach requires all the major project team members to be knowledgeable and active in the design process and to be committed to the owner's project team objectives. One contractor stated "To make a project go you have to be a team player; therefore you need people with confidence in themselves, and people who have an appreciation for the A/E's and owner's position in the project. If you have a weak owner, you shore him up. If you have a weak A/E, you work at making him stronger. Your responsibility is to the team and its goal."(Beard 1986).

Time savings are possible with the team approach because work can begin before all design work is complete. "With all members of the team working in concert, materials orders can be placed early and work can be planned precisely through each stage, thus saving time and eliminating inefficiency."(Greenhut 1989).

The articles cite several examples in which contractors under the team approach significantly improved constructability and or value engineering. One notable example of value

engineering was the Union Trust Tower, in Baltimore. One suggestion by the contractor, Howard C. Beck Company, during the design phase saved over $500,000 in curtain wall cost. Three-inch cold spring granite had been proposed for the building's skin, a very high quality and heavy material. The contractor suggested substituting a one and 3/16-inch veneer stone mounted on steel stiff-back trusses. The selection preserved the architect's aesthetic intent and saved the owner approximately four dollars per square foot over 140,000 square feet of wall area.(Beard 1986).

Budget control is improved because"the contractor is on the team right from the beginning...you can control costs from day one."(Greenhut 1989). A primary role of the contractor during the design phase is to estimate the cost of preliminary and conceptual designs so that accurate cost projections are known early in the project. "'If the owner's budget is $2 million, and the designer's preliminary drawings say it will cost $2.5 million, there's plenty of time to respond and to get that design on budget.'"(Greenhut 1989).

Early inclusion of the contractor in a team approach integrates budget control into every phase of the project, including the design (Greenhut 1989). Because the contractor is likely to have the most experience in buying construction materials, he is also best able to minimize construction cost (Greenhut 1989).

Specifically budget control is achieved by a process in which "Regular meetings give the participants opportunity to pool judgment and experience in budgeting, scheduling, and material selection. As drawings and estimates are developed, cost control is maintained through comparison with the budget price of the project." (Beard 1986).

Cost benefits are a result of value engineering suggestions or achieved through constructablity reviews by the contractor, whereas budget control results from a more general process of contractor involvement in a team approach. Budget control is not the result of changes suggested by the contractor but rather is the result of more accurate information througout the design process as a result of contractor's invovlement in the project team during the design process.

Teamwork and trust

A study on the behavior of decision making in project teams (Berzins and Dhavah 1989) identified trust as a key element of successful teams. It concluded that under the stress of time pressures, managers making decisions are more reluctant to place their trust in others. This in turn prevents the development of trust relationships and harms collaborative

decision making. Thus, teamwork is often hindered under time pressure by the tendency of decision makers to stereotype their team member's talents and abilities. For example, an owner might turn only to the architect to solve a design problem rather than consult with the entire project team.

Moreover, low-trust business transactions are dominated by extensive contracts that substitute for trusting relationships and increase the overall cost of business by increasing the associated bureaucratic costs. An ineffective team is often characterized by a climate of defensiveness, much of the creative energy of the team members is utilized to protect themselves. This is in contrast to high-trust environments, in which creative energy is focused on problem solving (Berzins and Dhavah 1989).

Accordingly, decision making within a competitive environment is typically driven by the fragmented motives of different team members (Berzins and Dhavah 1989). These decisions are based upon "positions" that a person may take in defending their "turf". Whereas within a collaborative process, team members develop a communal sense of responsibility for the success of the team (Berzins and Dhavah 1989).

Team communication

Problems are likely to occur when many people must work on complex projects. As technology increasingly becomes more

complex, good communication and coordination will be even more essential (Hensey 1987). A study on construction failures (Hensey 1987) found that the primary nontechnical cause for structural problems center around communication failures. As much as 25% of structural failures studied were related to some form of communication/coordination problem that resulted in inadequate design. Among the recommendations for greater communication were increased emphasis on "teamwork" and allowing more time for project team to evolve from a group of individuals into a cohesive team.

Moreover, the US House of Representatives Committee on Science and Technology held hearings in 1982 to examine the problems of structural failures in the US. The Committee identified two critical elements relating to communication that were noted as significant factors in causing structural failures: communication and organization within the construction industry; and the timely dissemination of technical data.

Hensey concludes it is essential that communication should be face to face and contact intervals should be short to avoid construction problems. He states "that frequent project team meetings are one of the most productive means of assuring needed communication on projects." (Hensey 1987). ASCE Quality in the Constructed Project concurred with much of Hensey's recommendations.

Phases of the project which are appropriate for the project team to consider as a group are 1) the defining of scope, budget, and schedule; 2) the refinement of scope-defining performance and quality criteria; 3) conducting alternate or feasibility studies which might affect scope; 4) assessing needed changes of scope on cost or schedule; 5) the end of the design phase; 6) evaluation of contractor's or supplier's suggestions for alternative methods or materials; 7) unexpected situations that require changes in schedule or costs; 8) significant problems in design or construction; 9) the end of construction (Hensey 1987, p.25)

In general, these studies on trust and communication all indicated that early and frequent involvement of the contractor in the design process helps minimize problems.

Liability

Litigation is a major problem in the construction industry. Integrating construction expertise into the design process creates potential liability exposure for individuals contributing that construction knowledge into the design. While much of the literature focuses specifically on the construction manager's input into design, many of the concerns expressed apply to any individual or firm that serves the same function as the construction manager in the

design process. In the team approach, the contractor is very much like a construction manager.

Tatum (1983) states that construction management consists of a group of management activities that are distinct from normal architectural and engineering services but are related to construction. These services may be provided during one or more of the project delivery phases: conceptual planning, predesign, detailed design, and construction.

In the design phase, the construction manager can perform essentially two roles. This individual assists in the overall formulation of the design by assuming primary responsibility for cost and schedule, advising the owner or architect/engineer on constructability, cost, and schedule implications of the design (Holton 1983, p.92)

Constructability recommendations include contract packaging, construction sequencing, construction cost, access to work, safety, multiple union work and jurisdictional problems, construction methods, materials, and minimization of construction interferences, as well as design detail improvements. These recommendations, which are advisory to the owner, can be applied in the early phases of design, when site layouts, schematics, and specification criteria are being considered. The construction manager can play a major role in preparation of project specifications involving field

coordination and control, work simplification, quality management, safety and labor provisions.

In the review of plans and drawings, the construction manager is expected to assist the owner by identifying planning errors, ambiguities, and omissions. The construction manager is not responsible for checking design calculations or for the technical content of specifications. At no time does the construction manager pre-empt the responsibility of the architect or engineer for facility design integrity. The construction manager's advisory role is that of making constructive recommendation, and presenting suitable design alternatives when appropriate. Alternate solutions may be particularly appropriate whenever design details affect construction feasibility, cost, or schedules (Conner 1983, Holton 1983, p.92)

In the construction manager's consultant role, construction experience and responsibilities are closely linked and the leadership role for the construction manager should exist only in those areas where construction knowledge is essential. Potential liabilities of the construction manager arise in three major areas of responsibility: design review, the preparation of project budget and schedule estimates, and design on site.

During design review, "If the general contractor takes a 'leadership' role in making recommendations on certain materials or methods, and these are adopted, he or she stands exposed to potential liability suits, especially if the decision to adopt the design was based on the owner's reliance on the knowledge and expertise of the construction manager."(Construction Management Committee 1987 p.93, Holton 1983, Lee 1982)

Given the wide net that is thrown in many lawsuits it is likely that any construction representative involved in the design stage will be named in a suit aimed at the design team. The court will probably examine the role of the construction manager in any questionable design decision brought into litigation (Holton 1983).

In the preparation of project budgets and schedule estimates, potential liability implications depend upon the extent to which the owner relied on the construction manager. For example, "the owner may believe that cost and schedule predictions are accurate in the same sense as professional designs, only to discover later that considerable reevaluating of scope and design are necessary due to overruns in budgets. In these situations, the construction manager could be exposed to many of the same risks as the architect/engineer, including loss of fee" (Sweet 1985, p.95-96)

Attempting to solve unexpected problems, the construction manager may perform many design-related functions that are not part of the formal plans and specifications. However, such designing on-site exposes the construction manager to increased liability. An example of this would be if a contractor built an extension to a hospital but discovered that the design for the connection between the old and new wing left a gap. The owner, under time pressure to open the new wing, might direct the contractor to install a temporary solution. The contractor might install a plate over the gaps, but if before a permanent solution could be installed a nurse tripped and was severely hurt, the contractor could be sued for an inadequate design.

According to the AIA and AGC construction manager contracts, the construction manager's role in design is "advisory only." If the construction manager is to take a more active role, then the construction manager must recognize the risk of increased liability.

In many project design-related activities, such as cost savings, feasibility, and scheduling, the construction manager should play a primary role, whereas in those functions affecting design integrity, the construction representative's role must be advisory.

Potential liability is a major consideration in the assumption of any design-related activities, especially in construction management, where the role and court precedents are not well defined. The construction management contract must clearly delineate the construction manager's responsibilities to manage this risk.(Holton p.97)

Tom Sweet, a legal scholar in construction law, argues that contractors who only suggest alternative construction methods should not incur design liability (Sweet 1985). Moreover, the construction manager who is principally a contractor will find that his comprehensive general liability coverage will not include design.(Sweet 1985)

But legal uncertainties create difficulties in defining the liability of contractors acting as construction managers. The construction manager does not easily fit into the traditional and legally established categories of owner, designer, or contractor. This task is often made more difficult when there is no agreement in the industry on the proper function of the construction manager.

The central legal question, whether the construction manager is more like a design professional or a contractor, depends on the form of construction management used. Is the construction manager engaged solely as a professional

adviser, or does the individual perform some construction himself?

For example, it has been held by the courts that a contractor can bring a negligence claim against the construction manager just as a negligence claim can be instituted against a design professional.(Sweet 1985 p.453). Nevertheless, much of this uncertainty will eventually be resolved as the construction manager systems become time tested and court tested.

In summary, the literature regarding the liability of contractors and contractors acting as construction managers, seems to indicate that the construction manager, or any construction representative during design, should take only an advisory role in actual design. However, it is likely that limiting oneself to a consultant role may not prevent the contractor from being drawn into litigation claims brought against members of the design team. The contractor and owner should recognize these risks and plan for adequate insurance to cover the increased risk.

Literature Summary

The literature suggests several benefits to early contractor involvement. Use of construction expertise in design results in cost or schedule benefits to the owner which are achieve through value engineering and constructability suggestions by the contractor. Furthermore a team approach to project team

structure also results in better budget control during design. In general, teamwork results in higher levels of trust among project team members and potentially improves communication. However, the literature also notes that the contractor's early involvement in the project team may increase the contractor's exposure to liability.

The remainder of this thesis will attempt to better understand how the contractor influences the design process, what the actual industry practice is for using the contractor, and when is it most appropriate to use early contractor involvement and a team approach. Part II is an in-depth examination of one structural decision for ROPA II and illustrates how the contractor influences design to improve budget control. Part III describes how a sample of development companies use the contractor in the project team. Finally, Part IV develops a model to provides a framework for evaluating when early contractor involvement and the team approach is most appropriate.

Part II. Riverfront Office Park II as an example of the team approach

Many of the studies in the literature related to early contractor involvement focused on benefits of improved cost and schedule. The literature also described improved budget control as a major benefit to the owner of a team approach to early contractor involvement. Accordingly, in order to better understand the benefits of early contractor involvement, an analysis of a major design decision during the Riverfront Office Park Phase II (ROPA II) will illustrate how the contractor influences the design process and improves budget control for the owner.

The first section provides general background to the entire project and describes how and why the contractor was brought into the project team. The next section attempts to look at a single decision made during the design process. Finally, an analysis of the process attempts to clarify how the contractor influences the design process and provides a better understanding of the benefits of early contractor involvement.

Project background and the contractor's involvement

Project description

The Riverfront Office Park (ROPA) was built in two phases: ROPA I was a 320,000 square foot speculative office building completed in 1982. ROPA II was a 330,000 square foot

speculative office building completed in 1987. Exhibit A is a rendering of ROPA.

The ownership interest included Codman Company and Macomber Development (also acting as the general partner). For both phases the project team consisted of Macomber Development as the developer, Cambridge Seven Associates as the architect, and G.B.H. Macomber as the contractor. In each phase, the project team worked together from the inception of the project.

Project History

The original idea for the Riverfront Office Park (ROPA) came from Larry Bianchi, a senior partner in the real estate brokerage firm of Codman Company. Larry Bianchi noticed that many high-technology users, such as software development companies, were founded in East Cambridge because of the area's proximity to MIT and had grown to become very successful businesses. However, according to Greg Luckas, a Codman broker, many of these firms were still leasing office space in "converted candy factories and warehouses."

Bianchi knew George Macomber on a personal basis, and asked George, in his role as CEO of Macomber Development, to assist in developing a speculative office building in the East

Cambridge area that would be targeted to these high-technology users.

With this project background in mind, it is possible to understand in greater detail the involvement of the contractor in the project team.

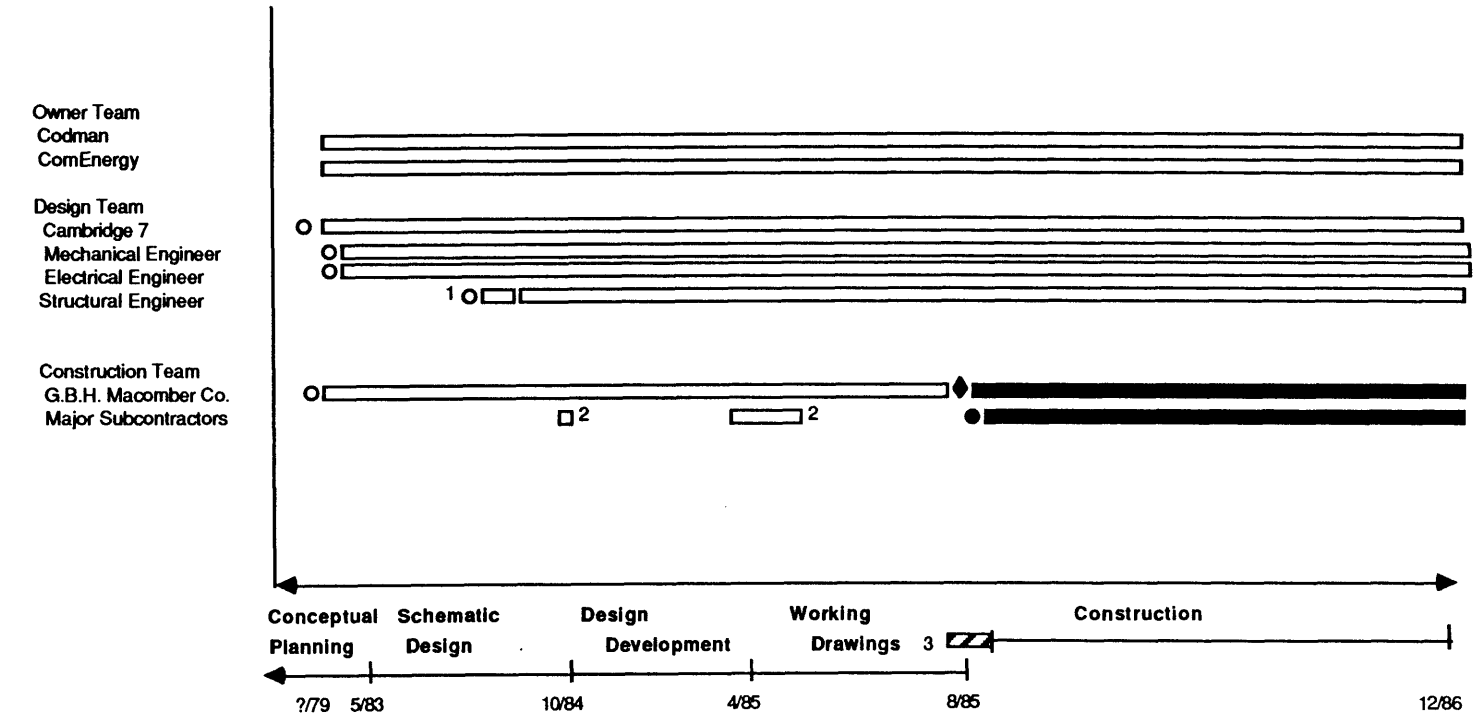
Early Contractor Involvement in ROPA II

Figure 1 provides a timeline of the involvement of the project team members for ROPA II. Project time is represented on the horizontal axis and is broken up into various development stages: conceptual planning-refining the scope of the owners program; schematic design-reviewing alternatives; design development-selecting and refining a single design; working drawings-producing construction documents for use in the field when constructing the building; and construction-the physical building of the project.

The vertical axis places the various project team members. Symbols represent how the project team member was selected. The length of the bars indicates the time period of involvement, and the shading indicates the type of relationship, agent or contractor, of the party to the owner.

Within this framework, an agent relationship is one in which the project team member is supposed to be acting in the best

interest of the owner, having a fiduciary responsibility to the owner. By contrast, a contractor relationship is one in which the party is paid and obligated to perform only those tasks specifically included in a contract. The interests of the project team member under a contractor relationship is one in which the team member is more likely to be looking after his own welfare rather than the owner's.



Negotiated Contract
Competitive Bid
Milestone
Consultant Relationship
Contractural Relationship

1Unpaid estimating service by sub-contractors
2 Selection of new structural engineer
3 Hazardous waste delay

Figure 1 - ROPA II Timeline

With this in mind, it is useful to describe how the services of G.B.H. Macomber Company were used very early in the building of ROPA. G.B.H. Macomber participated in some of the earliest conceptual planning meetings for ROPA because Macomber Development strongly believes in the value of early contractor involvement. In the past, this has included Macomber Development asking G.B.H. Macomber to assist in the initial site analysis before acquisition.

In addition, there is a special ownership relationship between Macomber Development and G.B.H. Macomber. George Macomber started Macomber Development and maintains a significant ownership interest in both companies. While Macomber Development is not required to use G.B.H. Macomber Company in all developments, there is a "friendly understanding" that G.B.H. Macomber Company would have the first opportunity to contract with a Macomber Development project. Because of this understanding that G.B.H. Macomber will probably get the construction contract, no agreement is signed or fee paid to G.B.H. Macomber for its preconstruction services.

Nevertheless, a guaranteed maximum price construction contract was signed with G.B.H. Macomber for ROPA II. This contract differed from the contract signed in ROPA I in that there were no shared savings if the construction price came in under the guaranteed maximum price; however, G.B.H. Macomber did receive a higher fee than in ROPA I. Byron Gilchrest, the project

manager for Macomber Development, explained that "This change was done because the second phase was thought to be largely a refinement of the first phase, and the ability to significantly increase project savings through value engineering and constructability reviews had been exhausted."

During design, the process of coordinating the project team became formalized in a weekly meeting in which 10 to 12 people would attend. The core members of the project team in ROPA II were: Byron Gilchrest, Charles Redmon, a principal for Cambridge Seven Associates, Ron Baker, a project architect for Cambridge Seven Associates, and Fred Wales, the project manager for G.B.H. Macomber. These core project team members were the same as those involved in ROPA I (although the team members were more actively involved in phase I). Other members of the project team that met jointly included the structural engineer, the mechanical engineer, various other engineering or construction consultants, a broker, and a property manager.

These meetings were very open in that all persons attending could participate in any of the decisions being made. Gilchrest stated that, "Rather than each person focusing on functional responsibilities of marketing, finance, and construction, the team must be focused on the project at hand."

Contractor influence in the design process under the Team Approach

The choice of structure, garage, and foundation for phase II represents, according to Ron Baker who was the project architect for phase II, "one of the finer moments in the project because every one worked well together in a cooperative process."

What follows is first a generalized description of the decision process and further background information. This then leads into a series of descriptions of the process from the perspective of the major project team members. While some of the information on the decision process is redundant the presentation of the multiple viewpoints is provided so that the reader can better understand the motivation and rationale behind each of the project team member's actions.

ROPA II Structure Selection Background

ROPA I was an all steel garage and office structure with a brick facade. Several innovations in the design were undertaken to accommodate the special needs of high-technology users. These design innovations included: 1) strip windows to allow for maximum flexibility for multi-tenant floors and exterior office configurations; 2) 100 pound live load capacity throughout the floor to allow for placement of computer rooms anywhere on the floor; 3) a 25% increased

electrical capacity to accommodate heavy use expected by operating a high number of personal computers and CRT screens; and 4) a 25% increase in cooling capacity to accommodate excess heat generated from heavy CRT use.

While ROPA I was completed in May 1982, much of the conceptual planning for ROPA II was conducted at the same time as the conceptual planning of phase I. However, intensive design work on ROPA II did not begin until the early part of 1984.

After completion of ROPA I there was a realization that the learning experience of phase I could be used to improve the design of phase II. Gilchrest asked all major participants of ROPA I to submit memos that reviewed the ROPA I design and made suggestions for improving design in ROPA II. After this information had been gathered, the core group of Byron Gilchrest, Fred Wales, and Charles Redmon sat in a room for an entire day discussing and reviewing the entire project while various subcontractors were brought in one at a time. According to Gilchrest, "A total of 50 man-days were spent by the entire project team on this review process."(Macomber 1987, p.4).

From the meetings, it was concluded that several design changes in the structure were necessary. First, it was noted that winds forces had created an unexpectedly high amount of twisting in the structure of ROPA I, and a stronger

reinforcement in ROPA II would be necessary. In addition, during the construction of ROPA I the contractor had experienced difficulties in construction because many cross bracing joints were poorly designed. Another structural change was a reduction in the amount and location of areas capable of accommodating the 100 pound live load capacity. A review of actual computer room placements in ROPA I showed that tenants had typically located the computer room only near the core of the building.

Furthermore, several problems were also noted for the garage. The aesthetics of the steel garage were unappealing, there were problems with cracking of concrete slabs and waterproofing, and there were unanticipated costs of protecting the exposed fire proofing from the weather.

Apart from these suggestion for physical changes in ROPA II design, the only change among the project team members was the selection of a new structural engineer. The new structural engineer joined the project team halfway through the schematic design process of ROPA II. Cambridge Seven Associates made the section based on Cambridge Seven Associates' past working relationship with the structural engineering firm.

During the schematic design phase, the structural engineer, architect, and contractor studied alternate plans for the structure of the office and garage. The intent of these

studies was to select a structure that minimized the problems encountered in Phase I and that would better achieve the owner's objectives for the project.

In phase II, a primary objective was an aggressive occupancy date. By the start of phase II the original planned unit development (PUD) permit for ROPA had expired and a new PUD permit had to be obtained. Also tax laws changes affecting depreciation periods would become effective in 1987. These changes would substantially effect project financial returns. The prime objective of phase II then was to receive a certificate of occupancy before the end of 1986 in order for the owners to receive the favorable tax treatment.

As a result of careful consideration of the structure by the project team, a concrete structure for the garage, floors 1 to 4, and a steel office structure, floors 5 to 13, were selected. Several factors were important in this decision, among them the price of the structure, the number of parking spaces in the garage, the ability to save time in the construction process, and improved aesthetics. This decision is analyzed in more detail below and illustrates how the contractor can influence the design process under the team approach.

As working drawings were being completed and before total project financing was set, unanticipated hazardous waste was

encountered on the site. This hazardous waste was discovered as test borings were done for the pile foundation, and its discovery effectively shut the site down for two months as studies were conducted and the contaminated soil was removed. This hazardous waste delay negated the potential construction time saving benefits of selecting a concrete garage and steel office structure. In fact, Fred Wales felt that the garage "probably ended up costing more than if we had stayed with the steel garage." but he still noted that the garage aesthetic had been noticeably improved.

A map of the flow of information during the decision process, figure 2, follows. This map attempts to synthesize of the owner's, contractor's and designers' recollection of the events that led to the decision for the structural selection. The vertical axis breaks up the actions by project team members, the horizontal axis is the sequences of events during the decision process. Arrows indicate the flow of information and the area inside the dashed box indicate when project team meetings were held and all information was freely exchanged.

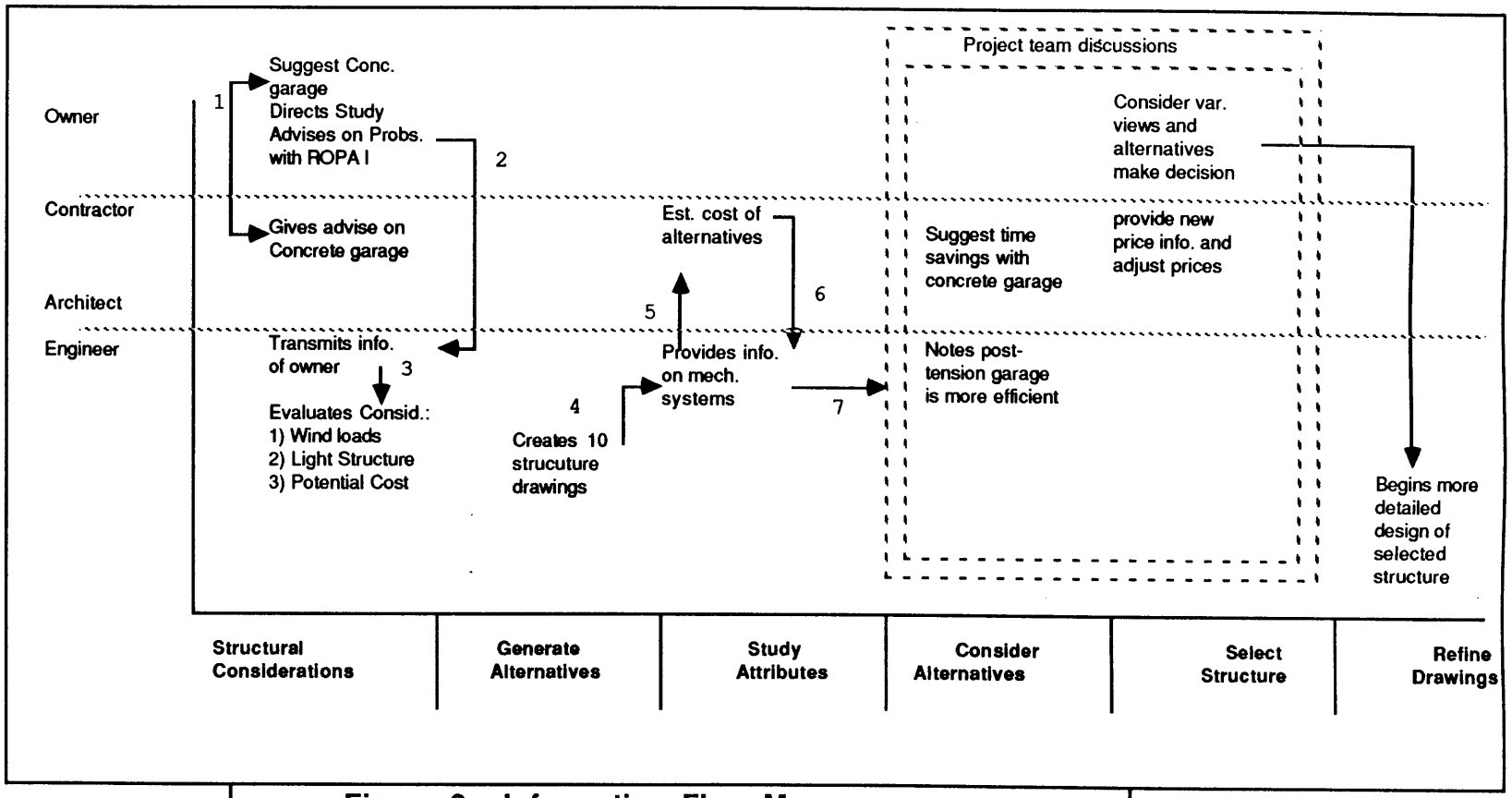


Figure 2 - Information Flow Map

The owner's perspective

Byron Gilchrest recollected that he initiated the process of reviewing the structure for aesthetic reasons. He disliked the appearance of the steel garage, and thought that a concrete garage would be more appealing. He recalled telling G.B.H Macomber of the idea for a concrete garage, G.B.H Macomber then studied the issue and suggested a post tension structure for the garage. This suggestion would allow wider spans and prevent the cracking of the concrete deck as happened in the ROPA I garage. After these discussions the structural engineer conducted a study of alternative building structures and the final choice was made during project team meetings when the drawings and pricing information of the various alternatives were available. Byron Gilchrest recalls that the decision for the final garage choice was, "partially based on aesthetics, the ability to accelerate construction, and the price."

The contractors perspective

Fred Wales of G.B.H. Macomber recalled that during project team meetings the issue of a new structure for the garage came up for discussion and that G.B.H. Macomber recognized the benefits of a potential schedule savings by using a concrete garage and steel office structure.

It should be noted that structural steel has a very long lead time for ordering and fabrication. This lead time in the case

of ROPA II might have resulted in construction start delays because the pile foundations would been finished long before the first steel arrived on the site.

Theoretically, a concrete and steel reinforced structure requires much less lead time. In ROPA II, floors one to four were a concrete garage structure, thus construction could have begun sooner and might have been complete by the time the first steel for the office structure arrived.

Fred Wales also recalled beginning the study of a new structure with the owner prior to selection of the new structural engineer. After the owner suggested a concrete garage, G.B.H. Macomber studied the issue and suggested using a drop-pan form for use in the garage.

When the structural engineer was hired, he developed several sketches of alternatives structures for ROPA II and gave them to G.B.H. Macomber. G.B.H. Macomber, with the assistance of various sub-contractors, estimated the prices of the alternatives. This information was then used to create a spreadsheet comparing the costs of the various alternatives developed by the structural engineer.

Over the course of several weeks, the various alternatives were discussed. As new ideas were generated in project team

meetings or as new pricing information became available, G.B.H. Macomber would provide additional cost information.

Fred Wales stated that there was "no question that the office structure would be steel." The more involved decision was between a steel or a concrete garage. Once that decision was made, the best alternative among concrete structures was the post-tension garage because it was the least expensive, and would solve the cracking of floor slabs.

According to Fred Wales, the decision to go with a concrete garage was chiefly motivated by the potential schedule savings. The steel structure was less expensive than the concrete alternatives. However, the expected reduction in overall construction time would compensate for the higher cost of a concrete garage. An additional benefit was the aesthetic quality of the garage.

The designer's perspective

Minhaj Kirmani, the structural engineer for ROPA II, recalled that they were hired when the building was half way through the schematic design stage. Because they like to take a "fresh look" whenever they are hired, they initiated the study of various structural alternatives. This project was unique because many of the major decisions had already been made such as floor to floor height and placement of the building core.

Kirmani states after he was hired and before developing the structure alternatives Byron Gilchrest advised him on areas of concern. These concerns were the result of problems encountered in ROPA I and included constructability problems associated with the first phase structure such as the cross bracing connections.

Similarly, Ron Baker recalls that one of the major reasons for the study of alternate structures was to avoid a repeat of the problems with the first phase garage. These problems included the exposure of the fireproofing to adverse weather, and problems with water proofing and cracking of slabs.

After meeting with the owner and project team, it was clear that the structural engineer had several factors to consider when designing the structure. Kirmani outlined these factors. First, a careful thinking through of the seismic and wind forces on the structure which, according Kirmani, "had never been thoroughly done." Next was to consider the pile foundations that required a light structure. The final consideration was minimizing the total price of the structure. In other words, the total price of the structure included the labor and materials cost for the structure as well as cost associated with the mechanical systems of each structure.

Exhibit B are the ten drawings that Kirmani produced as alternatives to consider the new structure for ROPA II. Figure 3 is a summary of the various drawings.

The ten drawings and list of seven complete structure, garage, and foundation alternatives provided enough detail for a conceptual price estimate of the structure. These ten drawings were sent to Cambridge Seven Associates where further refinements were done to help estimate the cost of the mechanical systems associated with each structure. After conceptual specifications for mechanical systems were done for each of the structure alternatives, the drawings and mechanical specifications were sent to G.B.H. Macomber.

At G.B.H. Macomber the conceptual estimator took the drawings and mechanical system specifications and estimated a total price for the alternatives. From the time the structural engineer completed the drawings to the time G.B.H Macomber came back with prices was approximately four weeks.

G.B.H. Macomber then produced a memo with a matrix listing the seven alternatives and their prices. Exhibit C is a memo from the architect that incorporates the G.B.H. Macomber price estimates. With this price information available, discussions at project team meetings centered around the various attributes and cost of the alternatives.

While Kirmani does not recall what the least expensive alternative was, the second cheapest structure was a steel office structure and a post tension concrete garage.

According to Kirmani, during the project meetings it was pointed out by the architect that the wide span garage structure alternatives were more efficient for garage parking. It was estimated that 43 additional cars could be parked with a wide span garage. When the two least expensive alternatives were compared on a per car basis, the post tension concrete garage was the least expensive alternative.

According to Ron Baker the price of the garage on a cost per car basis was the major reason for choosing the selected office and garage structure. Other reasons Ron Baker gave for selecting the post tension garage was that floor slabs were was less likely to crack and there was no need for fire proofing.

Drawing number	Description
SK1	Steel office structure with wide bays
SK2	Concrete office structure with narrow bays
SK3	Flat slab concrete garage with narrow bays
SK4	Post tension flat slab concrete garage with narrow bays
SK5	One way joist concrete garage with wide bays
SK5a	Post tensioned one way joist garage with wide bays
SK6	Sturctural steel garage
SK7	Precast concrete garage
SK8	Foundation for structure alternatives 1, 2, 3, and 4
SK9	Foundation for structure alternatives 5,6, and 7

Structure Alt.	Description
1	Steel office - concrete slab garage
2	Steel offcie - post tension slab garage
3	Concrete office - concrete slab garage
4	Concrete office - post tenstion concrete slab garage
5	Steel office - one way joist concrete garage or one way post tension concrete garage
6	Steel office - steel garage
7	Steel office - Precast concrete garage

Figure 3 - Summary of stuctural alternatives

Analysis of the ROPA II structural decision

This examination of the structural decision illustrates how the contractor influenced that process. Figure 2, the information flow map, shows how information flowed during the design process and clearly identifies the contractor's influence, the middle third of the map, in the design decision process. As described in the articles on the team approach, the contractor for ROPA II provided cost estimating services of preliminary designs. The contractor's early involvement thus provided the owner with more accurate cost information on which to make informed decisions. In the case of ROPA II, the contractor produced a spread sheet of the various structure alternatives which allowed the owner to accurately evaluate various structures based on comparable costs.

This decision also illustrates other benefits and attributes of early contractor involvement and the team approach. For example, during the project team discussions Fred Wales noted that the concrete garage structure could potentially reduce the ordering lead times and reduce overall construction time. These comments to save construction time are examples of improving the constructability of the project.

This example also illustrates how difficult it can be to quantify the benefits of early contractor involvement and the team approach. It is plain that cost savings were not the

prime reason for selection of the post-tension garage structure. Rather, a combination of aesthetics, schedule savings, and garage efficiency were viewed as the major benefits of the selection.

Additionally, this example illustrates the problems of relating potential benefits to the actual implementation. By using a structure of concrete and steel there was a potential for improved construction schedule but in the actual implementation of the decision these befits did not occur. In fact, the unexpected hazardous waste delay negated any of the potential schedule reduction benefits.

Beyond this, the free flow of information and the project team meetings that characterized ROPA II illustrate the collaborative nature of the decision process under a team approach. Specifically, the Stanford study described the free exchange of preliminary information as an attribute of a well coordinated project team. The passing of the structural engineer's sketches to the contractor and contractor's price information to the architect illustrates the cooperative nature of the project team members.

This example of the decision process also demonstrates the team playing nature of the project team members. Whereas each team member recalls different reasons for the selection of the structure, this does not necessarily imply that the decision

making in the project team was a competitive rather than a cooperative process.

Specifically, the literature on teamwork (Berzins and Dhavala 1987) indicated that decision making in a competitive environment is driven by the fragmented motives of the different team members. At first glance, the different reasons each of the project team members gave for selecting the structure appear to support a conclusion that decision making was fragmented. However, upon closer examination of the differing reasons given for the selection of the structure, it seems that each member was being motivated by what each interpreted as important for achieving the project's objectives. For example, Fred Wales recalls that the reduction in schedule was the prime motive for selecting the structure, the designers recall that the parking efficiency of the wide span garage was the major factor, and Byron Gilchrest recalls that aesthetics was also a primary reason for a concrete garage. These positions seem all to be based on a desire to advance the goals of the project, an indication of being a team player.

Finally, the concern for liability was not noted by the participants during the examination of the building structure. None of the major project participants, Byron Gilchrest, Fred Wales, or Charles Redmon, felt that the constructor was taking on additional liability. They stated that the contractor only

suggested alternatives and was never responsible for the actual designs. However, it should be noted that the close ownership relationship between Macomber Development and G.B.H. Macomber would have tended to reduce any potential litigation problems if they arose.

In summary, the ROPA II structural decision provides an illustration of how the contractor's early involvement in the project team under the team approach can influence the design process. In the example given the contractor was able to help the owner more accurately estimate project costs and evaluate structural alternatives.

However, simply knowing that there are benefits to early contractor involvement and knowing how they occur are not enough to understand when early contractor involvement and the team approach are most appropriate in a commercial development project. The next section of the thesis attempts to understand the differing rationales that developers have for involving the contractor in the project team.

Part III. Early contractor involvement in industry practice

Demonstrating that there are benefits to early contractor involvement does not necessarily determine whether or not developers will choose early contractor involvement in the design process. Therefore, this section focuses on actual industry practice of project team structure and reasons developers have for contractor involvement.

Before beginning an examination of the differing company strategies of project structure used in industry practice it is useful to understand the more generally accepted project delivery systems. Following this, one can better understand the differences in project team structure provided by the various the industry examples.

The project team structure of project delivery systems

The Stanford study suggested that the choice of the project delivery system was paramount in implementing a constructability program. For example, a traditional or "hard-bid" approach to contracting would have the contractor selected after all design was complete. Doing so, would preclude the contractor from contributing suggestions to improve design or making suggestions to improve construction techniques at the earlier design stage.

At present, project delivery systems can generally be grouped into three categories: the traditional method of the General Contracting System (GCS), and two more recent contract innovations the Construction Management System (CMS). and the Design-Build System (DBS). (CCM p.51).

In addition to the three project delivery systems, the team approach appears to be an approach to project delivery that is gaining greater acceptance. However, while the three generally accepted project delivery systems have been formalized into standardized contract documents created by industry trade organizations such as the American Institute of Architects (AIA) and the Association of General Contractors (AGC. The team approach has not.

These four project delivery approaches differ in the way they assign responsibility and functions among the various project team members. Kern (1982) has provided us a with a framework to evaluate the differing functions offered by project team members under the various project delivery systems. His framework graphically illustrates the multiple roles and responsibilities of the various project team members. Within this framework, project delivery is divided into five major functions. They are: the owner functions, project management functions, engineering-design functions, construction management functions, and construction functions (Kern ,1982).

Owner functions are those functions normally provided by the owner such as specifying the project's scope, contract type, project team structure, selecting the project team, monitoring performance, and providing approvals, project financing, and other tasks.

Project management function are those functions necessary to coordinate and monitor the performance of the many organizations and disciplines working towards the project objectives. While project management function are provided by each individual organization for its own scope of work, these are different from project wide functions that necessary for project delivery

Engineering/design functions are those functions normally provided by the architect and engineers, including conceptual studies, optimization studies, design calculations, design drawings, and design specifications.

Construction management functions are those functions related to the construction process. These functions include construction planning, contracting, procurement, and inspection during the construction phase.

Construction functions are those functions required for the actual construction of the project. They include providing

labor, construction tools and equipment, and directing the daily work.

Given the above framework, it is possible to graphically depict the different project delivery approaches. Figure 4 summarizes the various project delivery approaches. These approaches are the GCS, two forms of CMS, the DBS, and the team approach. A dark shaded area is an area of principle project responsibility, a light shaded area is an advisory or participatory role. The vertical axis divides the five major functions into owner functions, project management functions, engineering/design functions, construction management functions, and construction functions.

The solid lines connecting the project team members, owner,architect/engineer (A/E) and contractor (C), denote contractual relationships between parties. An A designates an agency or fiduciary relationship, a $ denotes a contractor relationship.

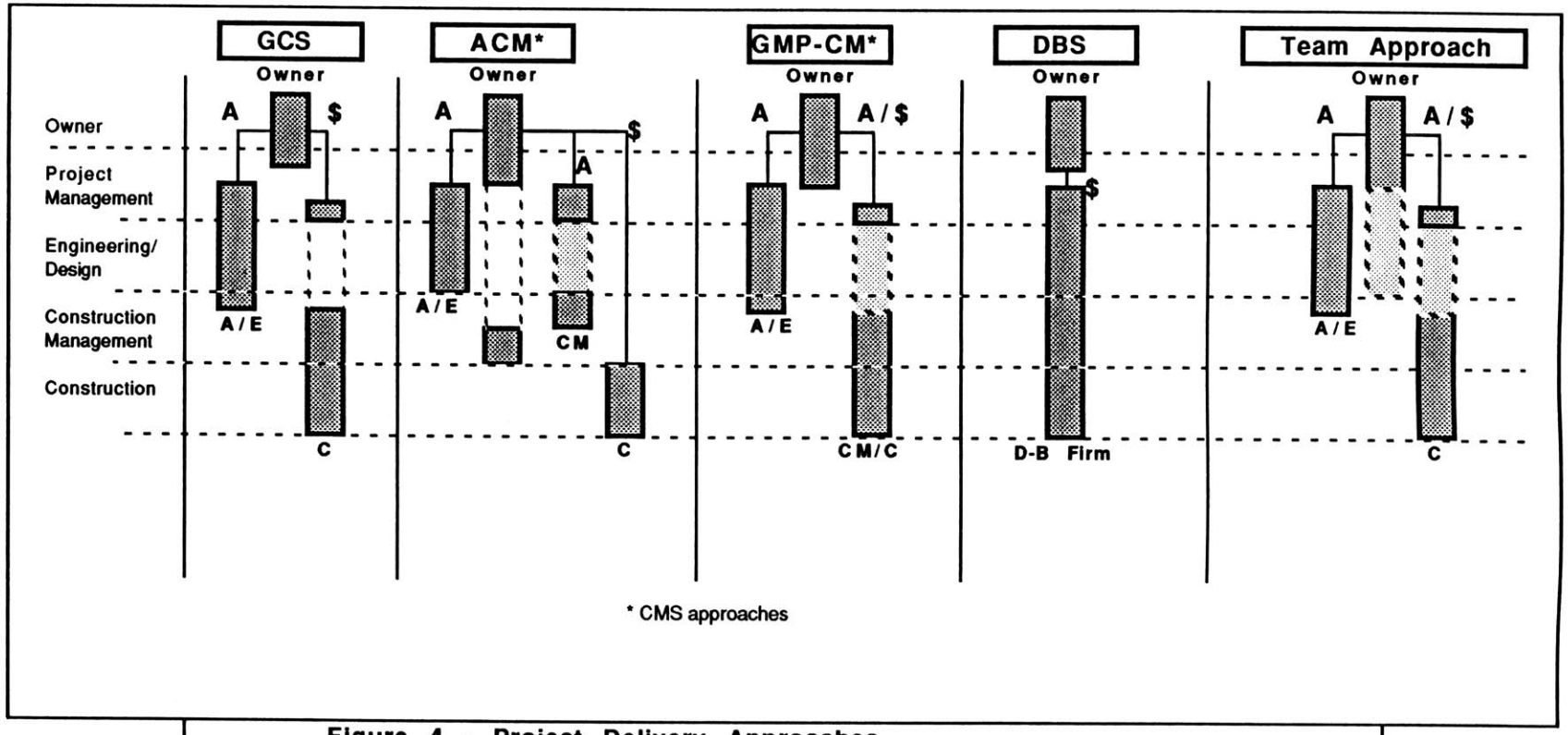


Figure 4 - Project Delivery Approaches

General Contracting System

In the traditional general contracting, "hard-bid" ,approach, the owner hires an architect to complete building design and prepare construction documents. The contractor is then selected through a competitive bid process. This approach separates the design and construction services by bringing the contractor on board after all the design work is completed. This approach precludes the contractor's input into the design process and also prevents advance purchasing until completion of all design work.

In the GCS, the architect is responsible for most project management and engineering/design, and plays a major role in construction management by observing construction quality. The contractor is responsible for construction and provides most of the construction management functions such as contracting and purchasing. The contractor and architect/engineer have no direct contractual connection but the architect does have a supervisory role over the contractor's work. Moreover, the architect has a fiduciary responsibility serving as the agent of the owner, while the contractor only shares a contractual arrangement with the owner, usually a lump-sum or Guaranteed Maximum Price (GMP) contract (CCM 1987).

Under this arrangement, the traditional "hard-bid" approach has limited ability to implement elements of a

constructability program (Barrie and Paulson 1984) because the contractor is excluded from the project delivery process until after design is complete. With this in mind, it appears that the construction manager and design-build approaches are better able to involve construction expertise early in design (Paulson and Barrie 1984).

Construction manager system

The construction management system can take several forms. The two basic forms are that of an agency construction manager or GMP-construction manager. Under the CMS approach, the construction manager is typically hired at the same time as the architectural firm. During the conceptual design and design phases, the construction manager assists the owner and architect by providing information on labor/material costs and availability to assist in selection and scheduling of construction methods. The construction manager may also assist the owner in contracting directly with the major subcontractor or trade contractors. It may also act on behalf of the owner to contract directly with the subcontractors. During the construction phase, the construction manager may oversee the quality of work by the various prime contractors. Finally, after building occupancy, a construction manager could be responsible for processing warranties, guarantees, and surety bonds.

While it is possible that a construction manager would perform many of these tasks, the tasks performed by a construction manager during a specific project depends greatly upon the variation of the construction management system used. Within the the agency construction management approach, the architect is primarily responsible for the design. Responsibility over project management is shared between the architect and the construction manager. The construction manager is responsible for most of the construction management functions; the owner is responsible for contracting and purchasing; and finally the contractors are responsible for construction. The relationship of the construction manager to the owner is purely an agent throughout course of project. The construction manager is an early member of the project team along with the architect and the owner, whereas the contractor does not participate in project meetings until near the start of construction. All contracts for design services, construction, and construction support services are directly with the owner.(Haltanoff 1988).

Another widely used construction management system approach is the guaranteed maximum price-construction management approach (GMP-CM). In the GMP-CM approach, the construction manager is responsible for contracting and purchasing. He is also responsible for construction, and typically performs some of the construction services himself. The construction

manager has both an agent relationship and a contractor relationship with the owner. Early in the design phases, the construction manager is an agent on behalf of the owner assisting in improving design. At a later point in design, typically when 70-80 percent of construction drawings are complete, the construction manager's agency agreement is amended to provide a guaranteed maximum price for total cost of construction. The construction manager's relationship to the owner changes at that point. Specifically, the construction manger has two roles, one as a contractor satisfying the guaranteed maximum price contract, and one as the owner's agent to perform the other construction management services.(Haltanoff 1988).

The ACM and GMP-CM construction management approaches described above are two among numerous forms of the CMS that have been created and each form has differing characteristics. The most basic form is the agency construction manager. Other approaches are: the owner-CM, the architect-CM, and the contractor-CM or GMP-CM. Each variation of the the CMS has unique benefits and potential problems.(Haltanoff 1988).

In general, with a construction management approach, the construction manager's technical expertise can be used to conduct value engineering and improve constructability early in the design phase. The construction manager is also able

to assist in advanced purchasing and complex scheduling requirements that are needed in fast track construction projects.

However, in the agency construction manager approach, greater risk is placed on the owner because there is no contractor to share the construction risks of cost over runs. In the GMP-CM approach, construction cost risks are shared between the owner and construction manager. But if the construction manager is also performing some of the contract work, there are potential conflicts of interest in the assignment of work to subcontractors and in the review and quality controls of work done by the construction manager.

Design-build

In the design-build approach the owner contracts with a single firm that is responsible for both design and construction. This allows maximum involvement of the contractor in design. However, the owner's involvement may be more limited in this approach.

Under the Design-Build approach, the owner signs a single agreement with a builder-design entity to perform both the design and construction of the project. The firm may have the design expertise in-house or contract out for architectural and engineering services.

In this approach the design-build firm is responsible for all the processes. Thus, the integration of design and construction services mean that the contractor's expertise can be fully utilized in improving the constructability of the project.

In addition, with the design-build system, there is a single source of responsibility. The firm is responsible for both the design and construction of the project, and the owner can more easily collect for deficiencies in either case from the design-build firm.

Team Approach

While the team approach is not a recognized project delivery system, in that no standard contracts for it are published by trade organizations such as AIA or AGC, it still may be useful to understand the approach in light of the framework developed by Kern.

Taken together, articles in trade publications, (Greenhut 1989, Beard 1986, Goodspeed 1989) outline a "team approach" to design and construction. These articles describe a process in which the owner selects the architect and contractor very early in the design stages of development. While the architect is responsible for the implementation of design decision, the project team meets as a group to cooperatively make many of those design decisions.

Under the team approach, the owner, in addition to providing approvals and funding, selects the project team and establishes the goals and parameters of the project. The architect develops the designs and engineering features of the building. The contractor's chief responsibility during the design is to provide advice on material and building systems, and during construction to focus primarily on construction management and construction of the project. While each team member is ultimately responsible for the results in area that he or she is responsible for, the project team member may not necessarily make all decisions effecting his work unilaterally.

Put differently, throughout the design process, the project team members meet as a group in regular meetings. At these meetings, the contractor contributes his expertise in building materials, construction methods, and project scheduling by suggesting alternatives to the architect's initial plans. These suggestions of substituting materials and construction techniques are intended to better achieve the owner's project objectives. Indeed, some have characterized the contractor as "a sort of owner's agent" under the team approach (Greenhut 1989). In other words, because of the contractor's responsibility to provide constructability and value engineering suggestions, the contractor shares an agent relationship with the owner during design. However, after the

guaranteed maximum price of the construction contract is established the contractor takes on more of a contractor relationship.

As a result of using a team approach, the owner should recognize there are implications for his own participation in the project team. Both the literature on early contractor involvement and nearly all interviewees that had used the team approach cited the importance of having very experienced and team oriented persons represent each of the project team members. Participants in the team approach felt that because of the interactive nature of the design process the owner should be more active and knowledgeable than an owner under the traditional approach. One architect felt that, "either the owner must be highly experienced and able to participate in design and construction or have total trust in his professionals."

Project team structure in industry practice

Having established a framework for understanding project team structure, it is now possible to analyze other project delivery approach and to consider the implication of these structures in terms of contractor involvement. While industry trade groups have established project delivery systems and clearly defined the contractor's role in contract documents, in actual industry practice, contractor

involvement in the project team is often a mixture of the three project delivery systems.

In order to gather the information on industry practice, several telephone interviews with project managers of large developers were conducted. These interviews were intended to determine the way different developers structured the project team and the reasons for that structure. Each of the developers provided as an example are among the 50 largest developers in the United States according to the National Real Estate Investor (1989). While with each developer the approach varies with the project, for those developers that were interviewed, there was a generic model that each prefers to use when developing a large commercial development project. The four companies presented, Gerald Hines Interest, Trammell Crow Company, Linpro, and Rouse Associates,represent an array of the diverse project team structures found during the survey of industry practice.

During the interviews three general questions were asked:
1) "How is the project team structured?" This question attempted to determine when the contractor was brought into the project team.

2) "Why was the project team structured this way?" This question sought to understand what the developers perceived as major concerns when structuring the project team.

3) "What are the chief benefits or lack of benefits of early contractor involvement in the development process?" This question sought to identify what each project manager thought were the key benefits and costs of early contractor involvement in the project team.

Through this process of interviewing developers, these four companies, each discussed in greater detail below, displayed the range of project delivery approaches and contractor involvement strategies found in the industry.

Gerald Hines Interests

Gerald Hines Interests has an in-house "conceptual construction" group of three to four people based in Dallas. This group was used to provide value engineering and constructability services for Hines' developments throughout the country.

After a site had been acquired, an architect was either selected based on past working experience or selected through a design competition. At about the stage of examining massing models, a member of the conceptual construction group flew out from Dallas to act as the consultant for the project through design until construction start. The conceptual construction consultant had information and experience based

on previous Hines developments and provided value engineering and constructability services to the project team.

It was not until after working drawings were complete that there was a bidding out of work to contractors. Additionally, these contractors were pre-selected based upon previous working relationships or local reputation. Hines preferred to have the steel, structure, and foundation work awarded as a lump-sum contract. By contrast, all other parts of the building were awarded under a guaranteed maximum price contract in which Hines took the lead in bidding out the mechanical, electrical, plumbing, and other major building systems and then assigned them to the contractor.

Not until after all the sub-contracts had been awarded, was the guaranteed maximum price for the portion of the job not included in the lump-sum contract set and the final contract signed. The project manager for Hines believed that this approach created incentives for the contractor to go after the lowest prices on the portions of the work for which it was responsible.

To help better understand the project delivery approach, adopted by each developer, two different figures are presented to illustrate different aspects of the process. The first figure concerns itself with a timeline of project team member selection and participation and the second figure

is concerned with the responsibilities of the different project team members.

Figure 5a graphically represents the involvement of project team members under the Hines approach in a timeline graph. Project time is represented on the horizontal axis and is broken up into the various development stages, conceptual planning, schematic design, design development, working drawings, and construction. The vertical axis represents the various project team members. The length of the bars indicates the time period of involvement and the shade indicates the type of relationship: agent, or contractor.

In addition, figure 5b uses the framework developed by Kern for describing the project delivery systems to illustrate each project team member's roles and responsibilities under the Hines approach. The Hines approach is similar to an approach in which the owner and construction manager are combined. Under the Hines approach, the architect was primarily responsible for the engineering/design but worked closely with the owner's conceptual construction group. Further, Hines preformed many of the project management functions that a construction manager might have performed. Finally, the contractor was primarily responsible for construction and construction coordination but shared with Hines responsibility in contracting and purchasing.

The Hines project manager felt that with both the assistance of a conceptual construction representative and the decision not to use fast track construction, that there was, "no need to bring in subs or contractors." The project manager further believed that the process by which Hines acquired construction services gave them a "competitive advantage" by lowering construction costs. They got lower prices because designs were very complete and because jobs were bid out.

In short, according to the project manager, the benefits to this approach were:"competitive prices for the foundation, steel, and structure, ability to control cost and quality of subcontractors, and a decreased exposure to change orders because completed designs and no fast track construction are used."

Nevertheless, some contractors dislike the Hines process. One contractor was quoted as saying that, "national developers such as Hines, Trammell Crow Co., and Lincoln Property Co. are taking construction management service 'one step further—they want to use your expertise, shift the risk to you and expect to pay you only a fee.'" (ENR May 1989).

Contractors have also complained that this approach hampers their ability to control risk. A subcontractor assigned by the owner may not have the same "level of commitment" to the contractor as one selected by the contractor.(ENR 1989).

Whereas contractors could at times control cost by applying pressure to known subcontractors, this was more difficult when using subcontractor with which it had no previous working relationship.

What is important to remember is that Hines chose not to use early contractor involvement and that it believes its approach to structuring the team minimizes construction costs.

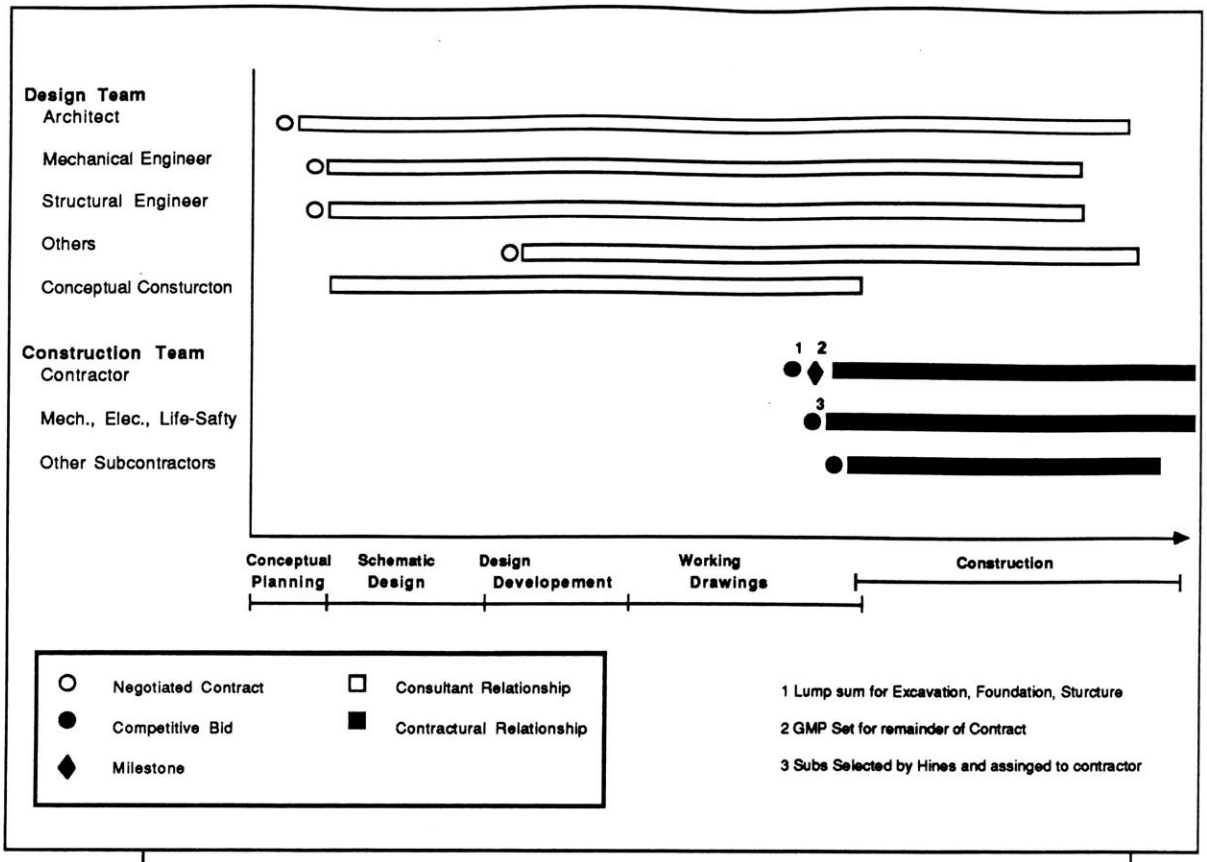


Figure 5a - Hines Timeline

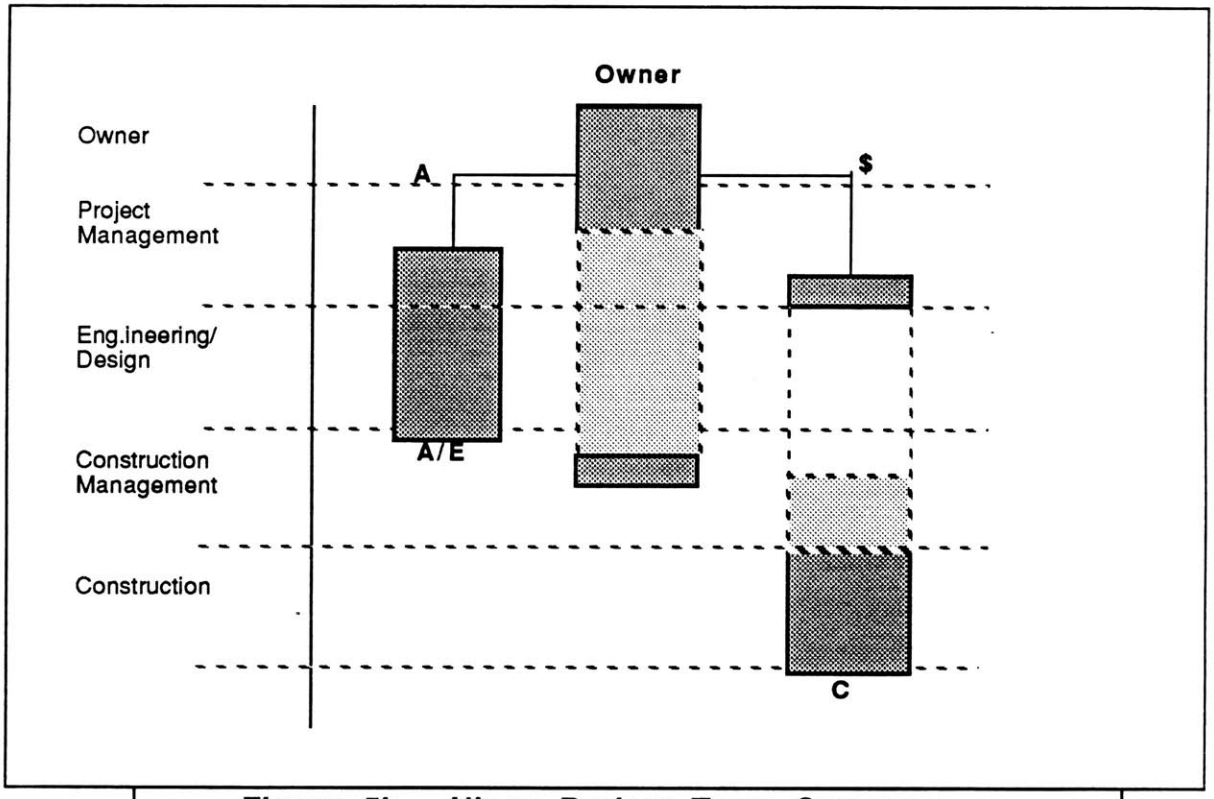


Figure 5b - Hines Project Team Structure

Trammell Crow-Washington D.C.

The D.C. Crow office had a great deal of in-house construction expertise. In some jobs their own company provided construction services. However when they did use an outside contractor the partners of this Trammell Crow office believed that early use of the contractor was not necessary.

Figure 6a illustrates the project team timeline for Crow and show the use of the contractor well into design. Crow preferred to assemble a highly experienced design team to complete the design work, "We select the best architects and engineers that money can buy." The principal from Crow stated that they paid fees of three to four percent for design services while the market was paying around two percent of construction hard costs.

While Crow depends on the architect and engineer to design a quality and cost effective building, the company may, between schematic design and design development, have asked a contractor to estimate construction costs but the contractor was not paid his services nor given any assurance of getting the final contract. It was not until after design development that Crow selected a contractor. Crow first preselected contractors, usually less than four, based largely on past working experience with the contractor. These contractors were then asked to bid on the basis of

design development drawings. The winning contractor was selected on a variety of issues, including price and quality. Finally, after this process a guaranteed maximum price contract was signed.

Crow project team structure, figure 6b, was a system that was most similar to the traditional general contracting approach. The architect was responsible for the design, engineering, and contract administration, and shared with Crow many project administration tasks. In the case of the contractor, he was responsible for contracting and purchasing, construction coordination and construction.

With this approach, the Crow principal interviewed felt that project costs could be minimized. In fact, the Crow principal referred to early involvement of the contractor as, "a lot of unnecessary hand holding." He believed that the contractor's suggestions did not result in significant cost savings, and commented that, "they have no bright ideas. Since many CM firms sub out everything, they have no concept of how to actually do the work." In addition, he felt that early use of the contractor would add about two percent onto the fee over a competitive bid contract.

Bearing this in mind, Crow's approach, like Hines', did not use extensive contractor involvement in the design process. Lowering the price of the construction contract was thought

to be more important than the marginal benefits of the contractor's involvement.

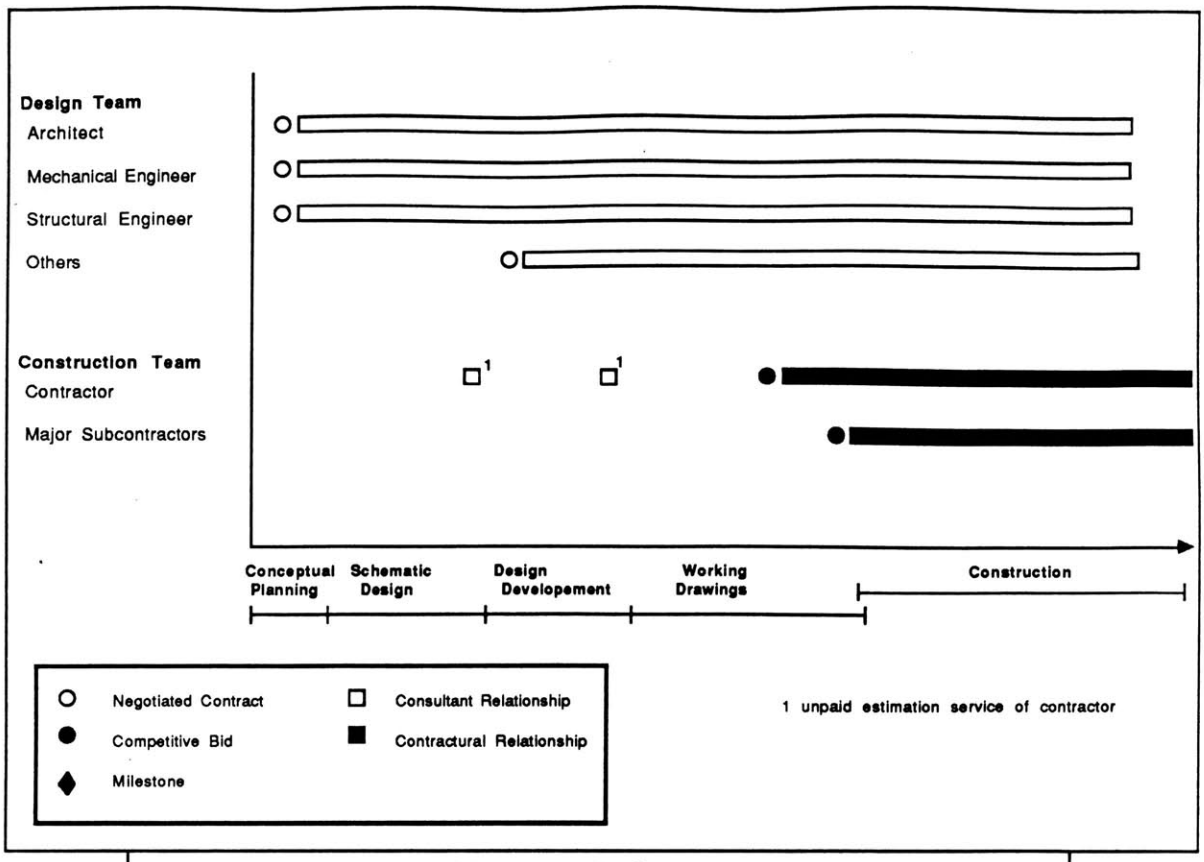


Figure 6a - Trammell Crow Timeline

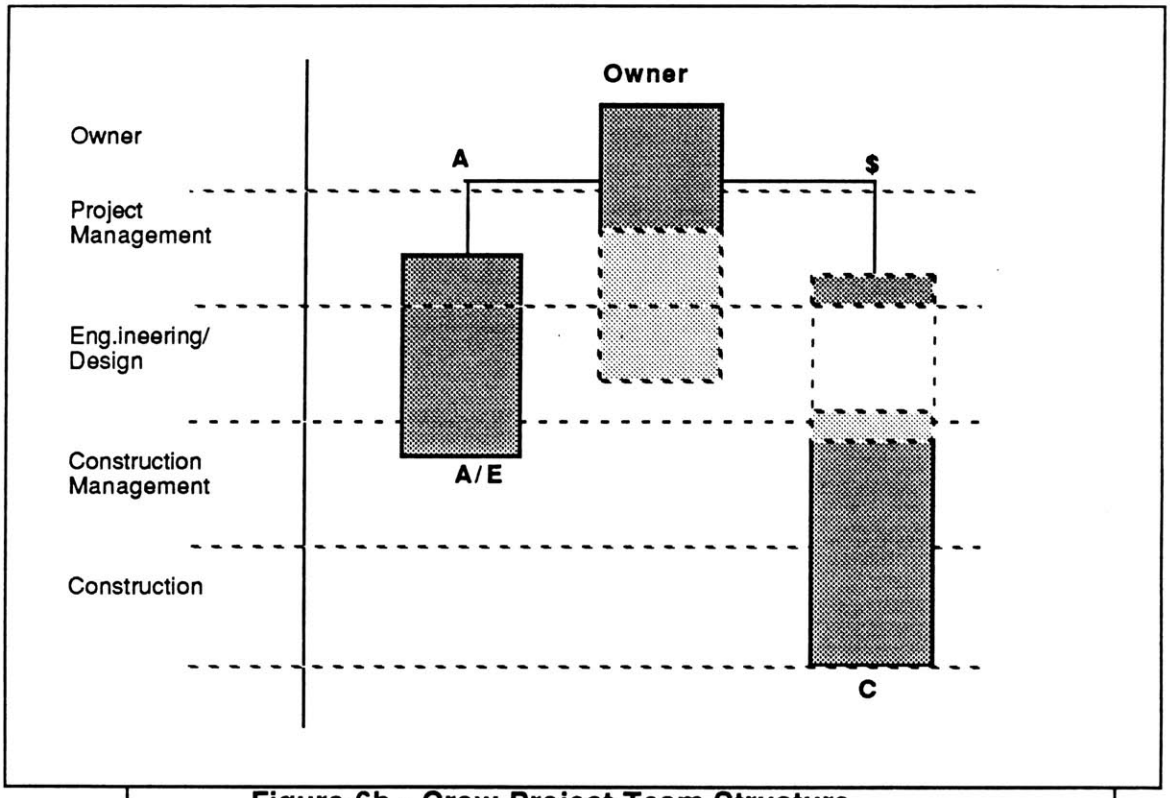


Figure 6b - Crow Project Team Structure

Linpro

In contrast to Hines and Crow, Linpro used an approach in which the architect and contractor were generally hired at the same time very early in the process during the conceptual planning stage. These project team member's involvement in the project team is summarized in the timeline of figure 7a. The contractor typically negotiated a guaranteed maximum price construction contract with a 5% fee. However the actual guaranteed maximum price that the contractor is committed to bring the project cost under, was not set until after design development and before working drawings were complete.

In addition, the contractor was paid a fee during the design phase of the process, but the developer called these fees a "joke" and considered them more of a token of sincerity than payment for services. Instead, the cost of these preconstruction services were rolled into the project construction costs and these costs remained unpaid until they could be taken out of construction loan draws. This reduced the up-front costs paid by the developer and shared some of the up-front financial risk with the contractor.

The contractor's role during the design phase, included participating in project team meetings that included the owner, architect, and other consultants as they were needed. These meetings were held as often as necessary, during the

conceptual planning and schematic design stage this may have been bi-weekly, and during design development this may have been weekly. Linpro liked to operate the meetings with an open format in which all aspects of project were discussed and all members were encouraged to contribute on aspects of design, constructability, and construction methods.

Throughout this process of project team meetings during design, the key role for the contractor was to continually refine cost estimates at various design stages. Contractors typically accomplished this with the aid of a select few subcontractors. In the conceptual planning stage, the contractor relied on in-house expertise and cost estimates. At the schematic design stage, a contractor might have asked a single trusted subcontractor in each of the major trades to provide estimates of the plans. During the detailed design phase, three trusted subcontractors for each trade would have provide estimates before the contractor committed to a guaranteed maximum price set in the contract.

These subcontractors were not compensated nor was there an explicit guarantee of receiving the work. The subcontractors' estimation services were performed as a service to the contractor to gain an advantage when the job was actually bid. Typically the subcontractors involved in the pre-bid analysis did have an edge in the process. In fact, contractors who used this approach estimated that these

subcontractors received the job "greater than 50% of the time."

In addition, while there were no written guarantees of receiving the job, some contractors gave the preferred subcontractor a right of first refusal. If the preferred subcontractor was competitive with the lowest bidders then the contractor would go back to the subcontractor and tell him he was competitive and asked if the subcontractor was willing to lower it bid price.

The actual selection of the subcontractor took place after pre-selected subcontractors were asked to submit bids and the selection of subcontractors was discussed in project team meetings. The contractor may not have sought to select the lowest bidders. A common feeling was that "if the bid is too low, then the sub is skimping in some area or is leaving something out."

Taken as a whole, Linpro's approach was most similar to the team approach as described in the literature. The architect was responsible for design and engineering with input from the contractor. Project management responsibilities were shared jointly with the owner. Finally, the contractor was responsible for the contracting and purchasing, construction management, and construction. This project team structure is summarized in figure 7b.

Finally, Linpro believed that the contractor should be included as early as possible in the development process and that the chief benefit of this involvement was "minimizing risk to cost overruns."

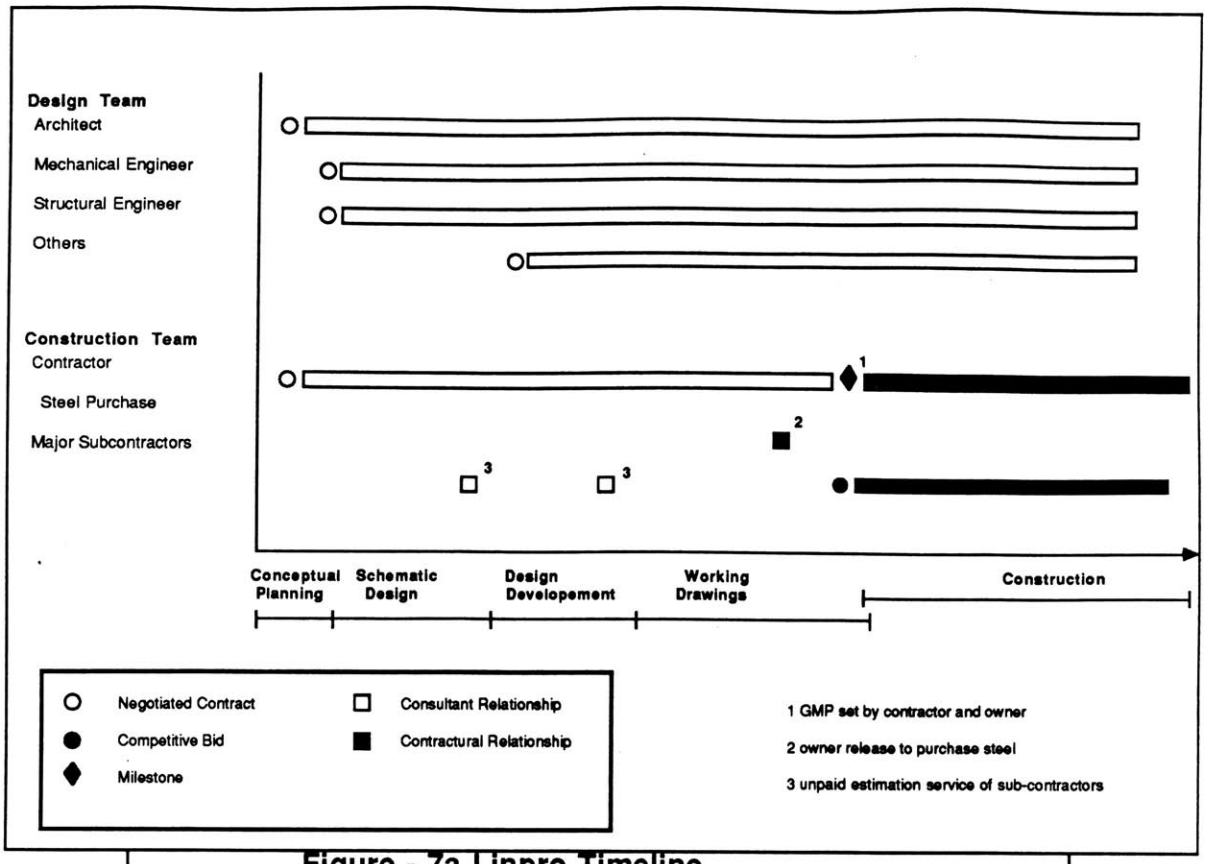


Figure - 7a Linpro Timeline

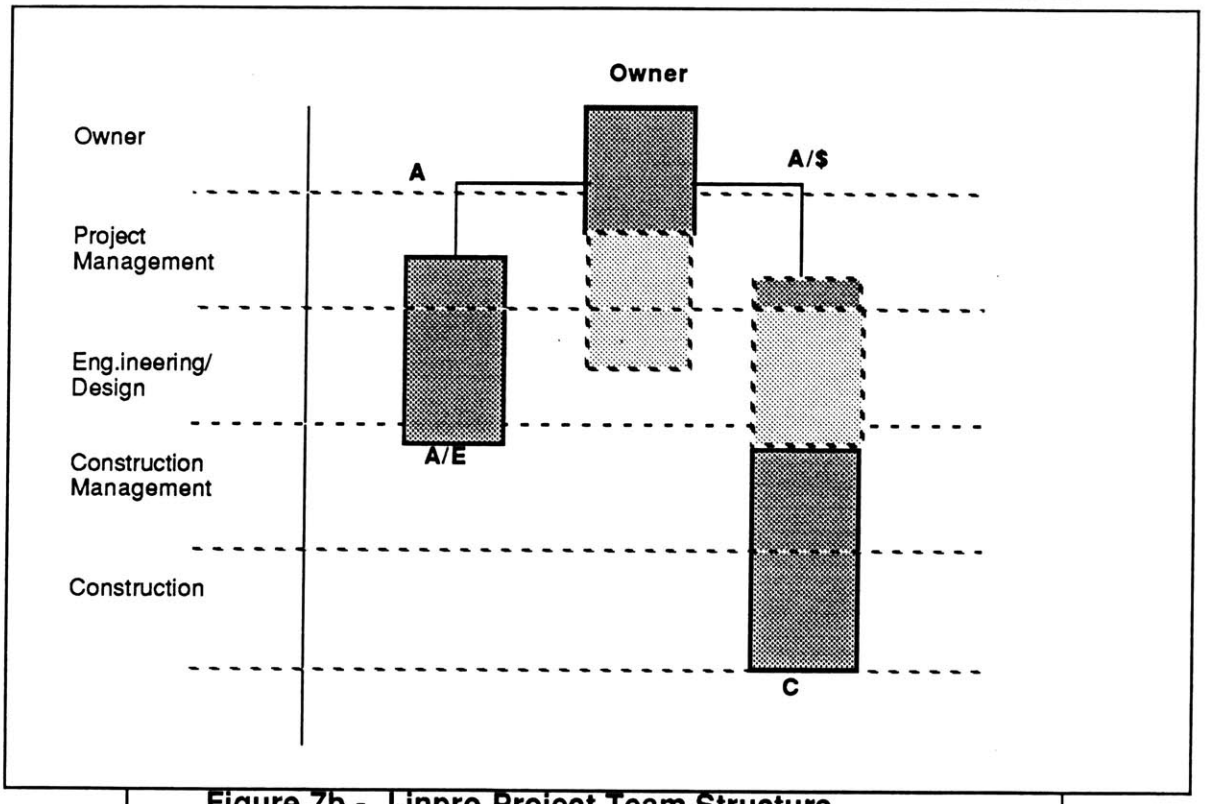


Figure 7b - Linpro Project Team Structure

Rouse Development, Washington D.C.

Like Linpro, Rouse also had a practice of early involvement of the contractor. The project manager from Rouse believed that the architect tended to be less capable of handling the technical side of the design and therefore preferred to bring in construction expertise early.

Constructability and scheduling were important issues because many of Rouse's developments were large mixed-use projects. The retail portions were typically a large component of of these projects, and it was critical for retail tenants to open for business at key points in the consumer buying seasons, August or pre-Easter. As a result, the cost of not meeting occupancy dates was significant.

The architect and contractor were selected as early as possible during the conceptual planning stage. Figure 8a illustrates how this fits in to the timeline of structuring the project team. An agreement was signed with the contractor to provide pre-construction services with the understanding that the work would be open to bidding later. Rouse believed in paying a "fair price" for pre-construction services because they did not want to feel obligated to the contractor. Under this arrangement the contractor served as a consultant on "cost, constructability, and schedule" throughout the design process.

Rouse has a practice of contracting directly with the subcontractor for the mechanical, electrical, and life-safety systems. In just those systems design-build agreements are signed after design development is complete. This was done because of the complexity and coordination problems associated with these systems. The project manager believed that the practice of signing design-build agreement for major portions of the contract, "has worked well in the past, other wise there tends to be omissions or they cost too much." The contracts were typically cost-plus with a guaranteed maximum price, however, at some point, if work was progressing satisfactorily, Rouse may have decided to convert these contracts to lump-sum agreements and avoid the bother of contract monitoring.

According to the project manager, the rest of the construction contract was bid out after design development was complete and a second contractor was chosen for the construction phase of the project. However, if there were specialty items, Rouse may have purchased these items in-house or contracted with the contractor in a separate agreement from the guaranteed maximum price construction contract. Because, Rouse is primarily a retail and mixed use developer, these speciality items tended to be for retail uses such as special store front doors.

Rouse also has a practice of involving the first contractor in regular project team meetings as a means to bring together the various project team members into the design process. During the early stages of design, conceptual planning and schematic design, the meetings were monthly and tended to be large including the architect, mechanical engineer, structural engineer, contractor, owner and other consultants. During design development, there were many more meetings, bi-weekly, but smaller because these meetings tended to be focused on particular systems. During the working drawing stage the meetings were very large because everyone had to be included during the coordination process.

The Rouse approach appears to be a hybrid of the CMS and design-build approach. The architect was responsible for design with the first contractor providing input in design. The pre-construction services of the first contractor are similar to a construction manager's responsibilities in the agency-CM approach. By comparison, the second contractor, selected after the bid, was responsible mainly for construction management and construction. In addition, Rouse took a very active project management role and took on some of the contracting/purchasing responsibilities. Finally, The design-build contracts with the three major subcontractors meant that each subcontractor was responsible for the final design, purchasing, and construction of its portion of the project (see figure 8a).

The project manager interviewed was "not quite" sure why they used this system of project structure. The key benefits as he saw them were that this was "an efficient way to do it" and that they had the ability to "control price" by changing contractors. The project manager also felt that this system was very flexible in responding to market conditions because they had the in-house experience to go out and seek the best price in the market for specialty purchases.

In summary, Rouse believed in early contractor involvement but did not think it was necessary that the contractor used in design be the same as the contractor used in construction. Additionally, Rouse seemed most concerned with meeting occupancy dates and the ability to control prices.

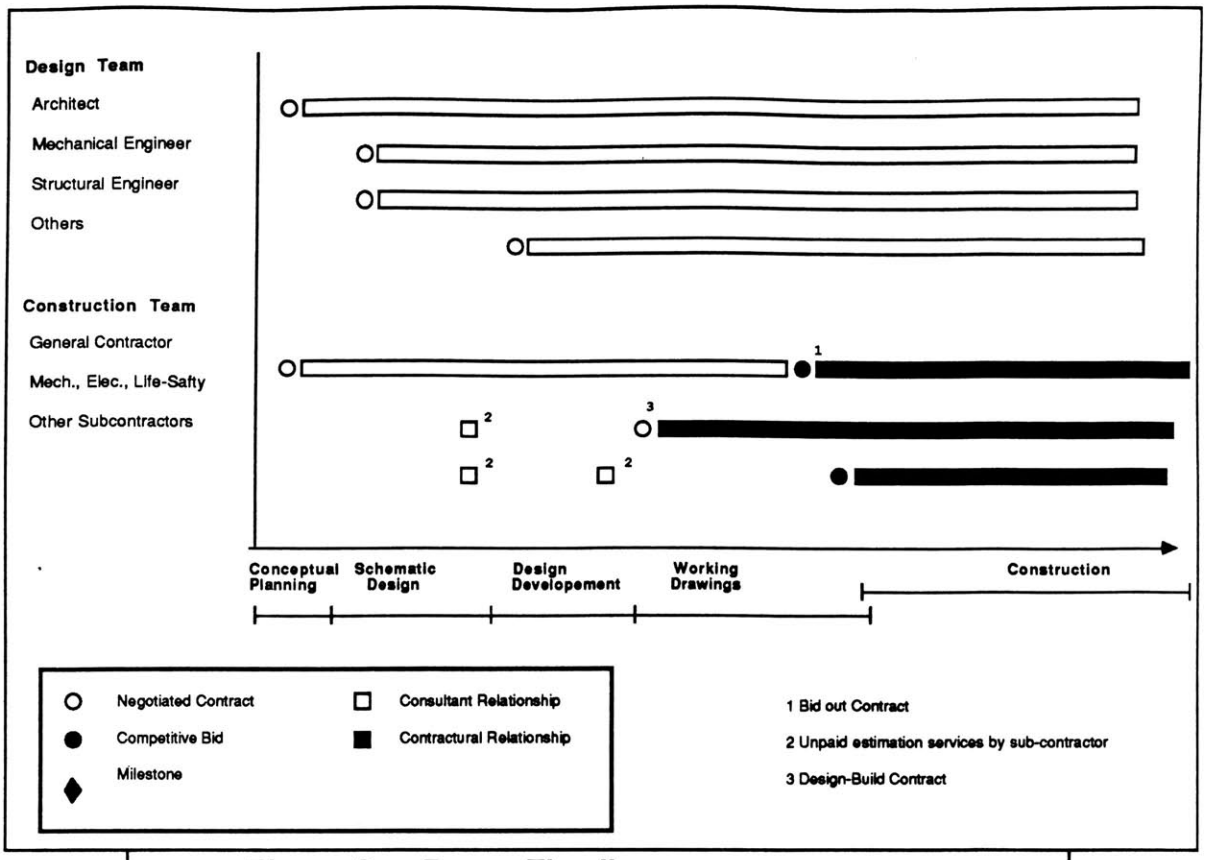


Figure 8a - Rouse Timeline

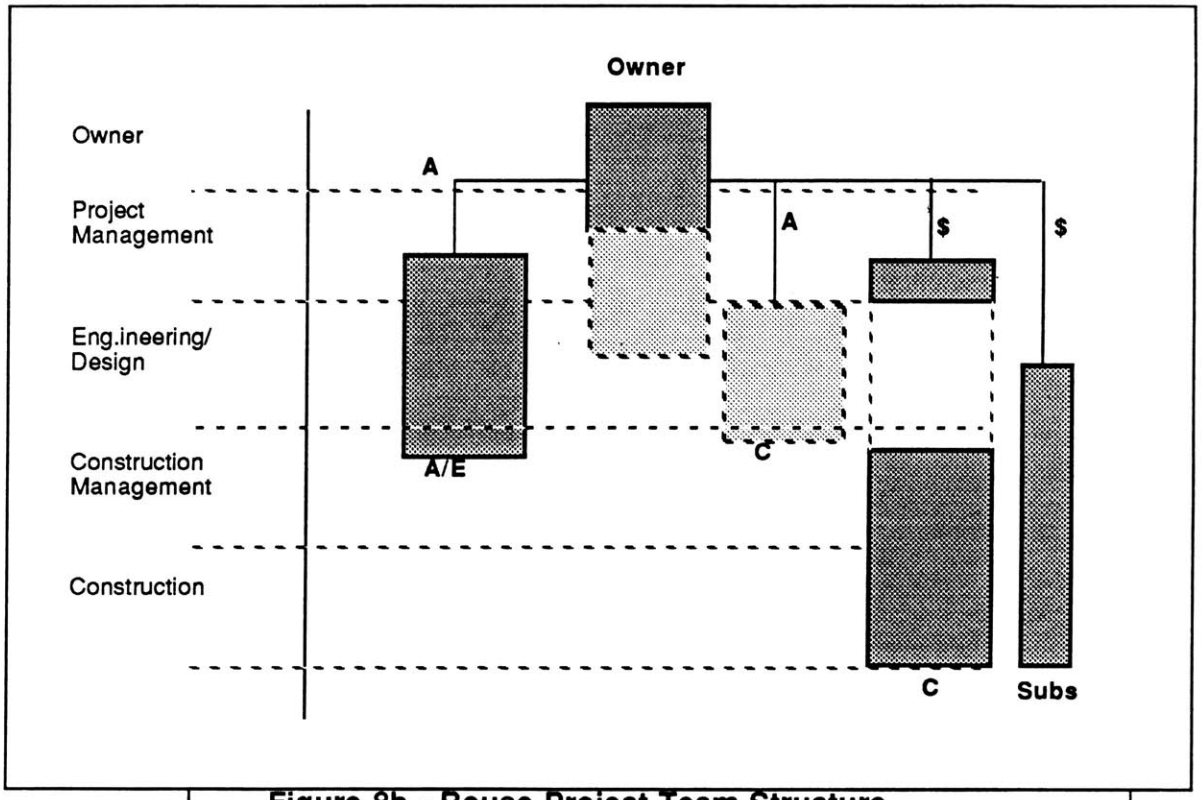


Figure 8b - Rouse Project Team Structure

Comparison of the Actual Examples to Project Delivery Systems

What we have seen so far are four very different project team structures and within each project team structure a different use of the contractor. In order to draw meaningful conclusions from this information it is necessary to analyze these examples and look for a pattern of contractor involvement to emerge. This is first done by comparing the industry examples with the previously established project delivery systems. This is then followed by a review of the reasons for selecting a project team structure.

Owners' choices of project team structure

It is apparent from the examples that none of the approaches actually used by the companies exactly matched the project team structure described by the various project delivery systems. However, even though each of the companies had a unique way of structuring the project team and involving the contractor, one clear way of distinguishing the companies is by when the contractor was brought into the project team. Linpro and Rouse involved the contractor early in design process, hiring a contractor at nearly the same time as the architect. Hines and Crow did not involve the contractor until after much or all of the design work was complete. Figure 9 illustrates the differences across companies between when the contractor was brought into the project team. On the vertical axis are the differing companies, and the

horizontal axis represents the development stage when the contractor was brought in.

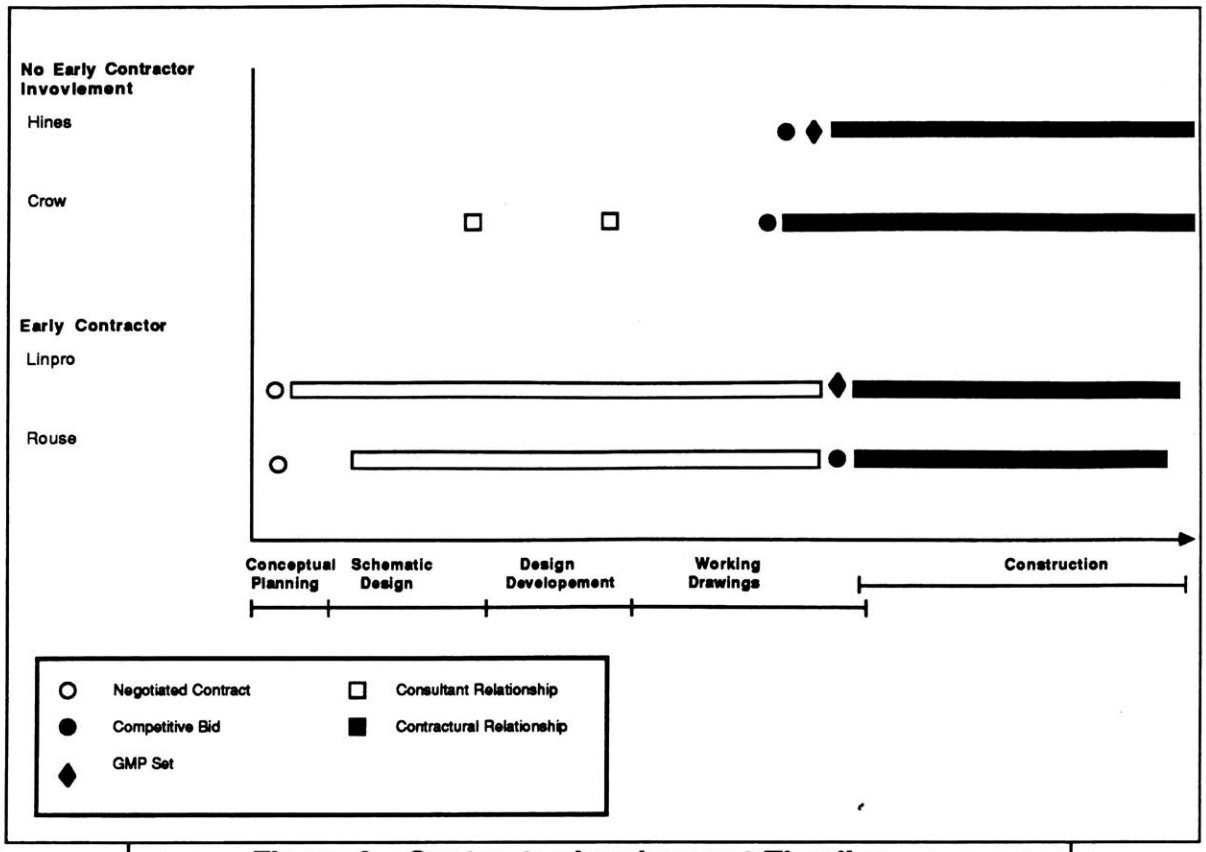


Figure 9 - Contractor Involvement Timeline

An interesting pattern seems to emerge from the examples studied above. Those companies that chose not to have early involvement of the contractor also chose to assign the contractor's responsibilities in a manner quite similar to the GCS approach, whereas those companies that had early contractor involvement tended to structure the contractor's involvement in a way more similar to the one of the CMS structures.

Figure 10 compares the project team structure of Hines and Crow with the GCS. In both these cases the contractor's role was limited mostly to construction and construction management. Hines provided much of the construction expertise in the design process from its in-house construction group. While Crow was also active in the design process, it relied upon the architect and engineers to design the project without a great deal of assistance from a contractor.

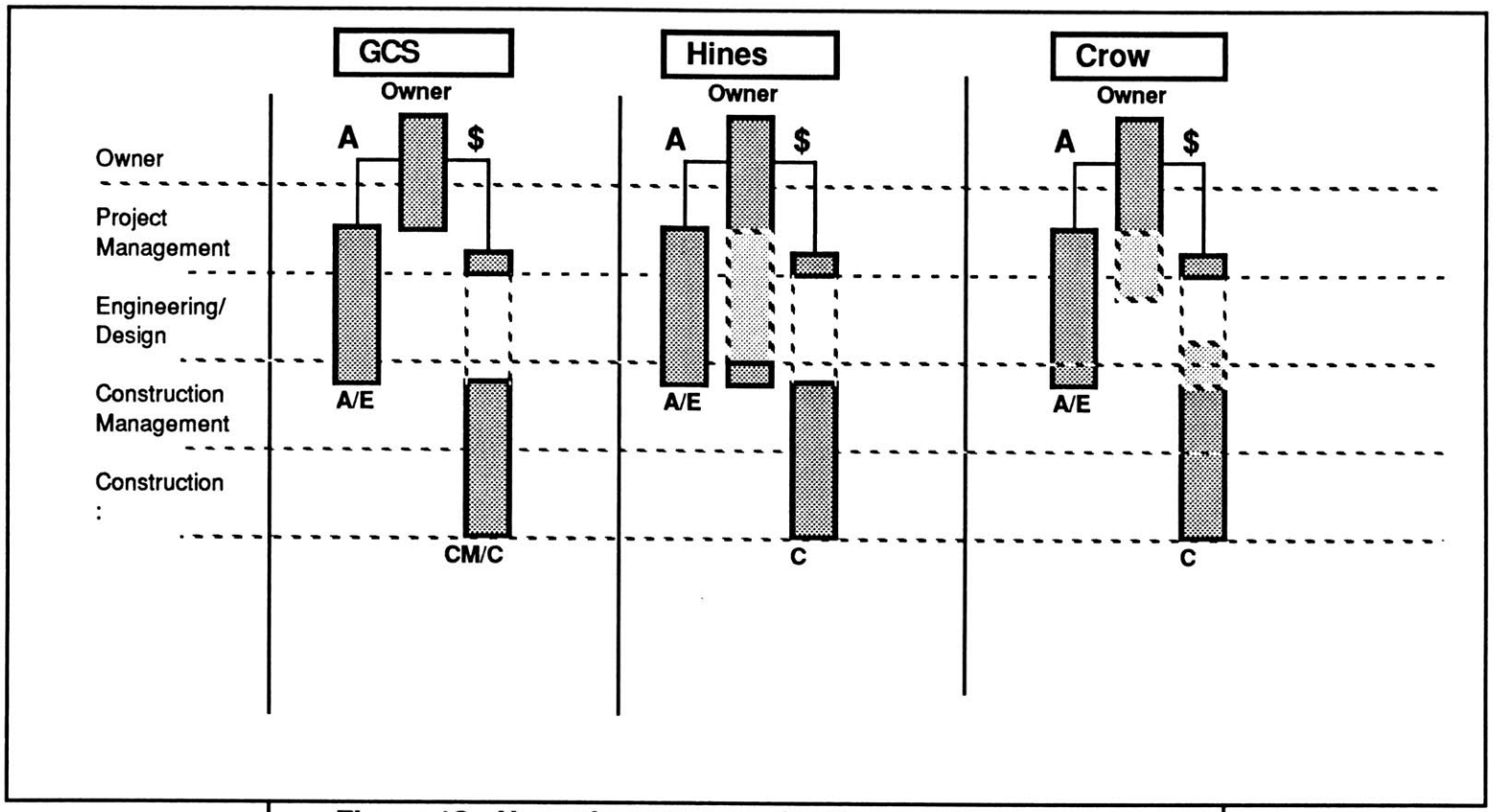


Figure 10 - No early contractor involvement

Figure 11 compares the project team structure of companies with early contractor involvement, Linpro and Rouse, with the GMP-CM structure. With both companies, the contractors provided construction and construction management services and also participated in the design process. The contractors in both cases provided cost estimation information and participated in project team meetings by contributing constructability and value engineering suggestions.

With Linpro's approach, also a team approach, the owner, architect, and contractor worked together throughout the design process. The contractor's role was almost identical to that of the construction manager in a GMP-CM approach.

This is compared to Rouse where, the contractors' responsibilities were similar but they were divided between two different contractors. The first contractor's early involvement was also similar to that of a construction manager under an ACM approach whereas the second contractor's responsibilities during construction were most similar to the contractor's role under the GMP-CM approach less the design involvement. In addition, Rouse's approach is further complicated by the separate design-build agreements that were signed for the three major building systems. The effect of this is to make Rouse more of a hybrid approach of the CMS and the DBS.

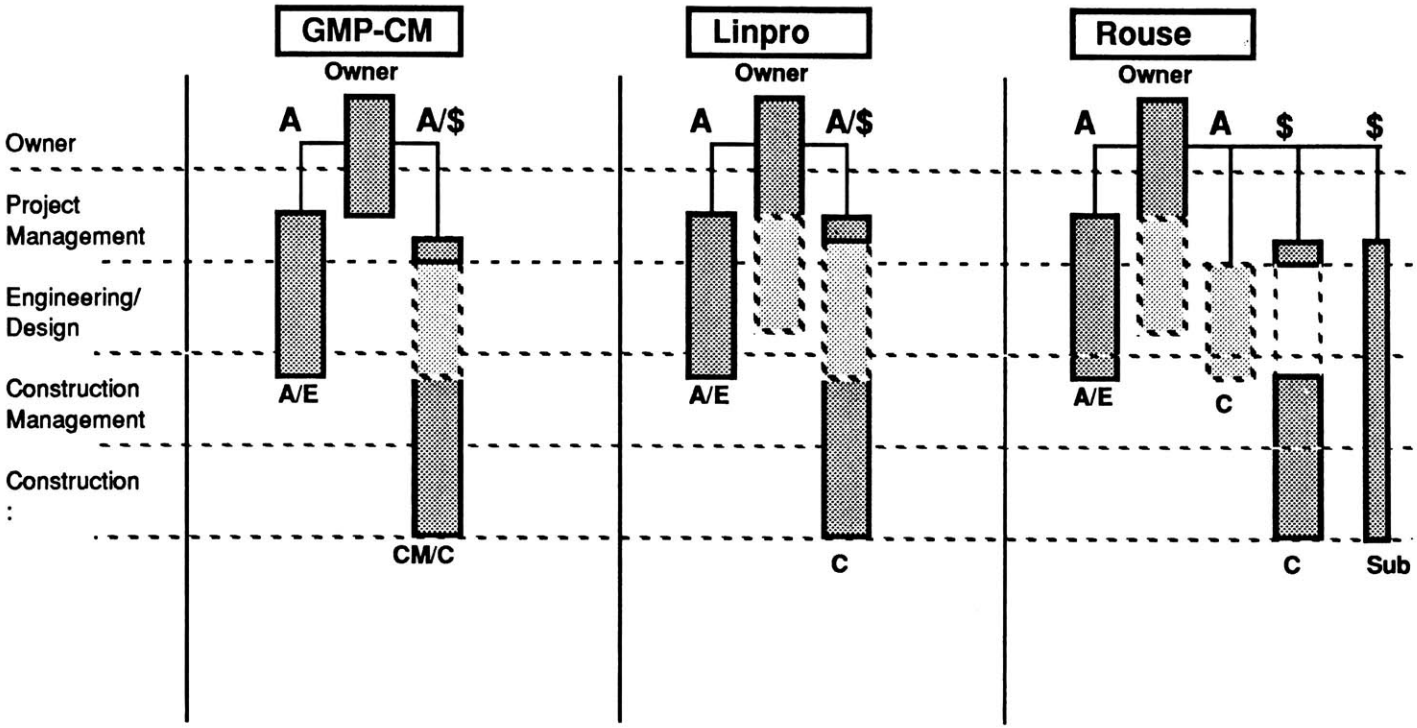


Figure 11 - Early contractor involvement

Owners' reasons for choice of project team structure

The differences in project team structure can be examined at an even deeper level by trying to understand the rationale behind each approach. All the developers interviewed were concerned with improving cost effectiveness and desired a balance between high product quality, cost, and schedule. The developers all reported a tendency to rely upon a limited number of contractors that they had worked well with in the past. One project manager stated that, "Preselection of the contractor and or subcontractors is a major prerequisite for a successful project." This was because of the ability to assure that the contractor was capable of performing quality work and a good working relationship existed.

However, differences did emerge in the reasons for structuring the project team. Those companies that preferred not to use early contractor involvement seemed to feel that minimizing construction cost was the major project objective whereas, those companies that used early contractor involvement felt that budget control and reducing construction delay were the most important project objectives.

Hines and Crow both chose not to use early contractor involvement. Both companies stated that competitive pricing was a major benefit to their approach. The Hines approach to minimizing cost was to take a very active approach in

contracting, and Crow relied upon the competitive bidding of the construction contract to kept costs low.

These reasons contrast those given by companies that did involve the contractor early. Both Linpro and Rouse used the contractor early and felt that factors other than just minimizing cost were very important for the project. Linpro stated that budget control was the major reason for early contractor involvement while the Rouse representative stated that ability to control prices and meet occupancy dates were a major benefit of its approach.

However, as a consequence of using the contractor early in design, both companies felt that they in some way paid for these preconstruction services of the contractor. Linpro stated that the services were paid indirectly in the form of a higher fees during construction, while Rouse paid for the contractor's preconstruction services more directly with fees during design.

Figure 12 is a summary of the responses of the companies to the questions of when the contractor was involved, why they chose to structure a the project team a particular way, and what they perceived to be the benefits and costs of early contractor involvement. The companies that did not have early contractor involvement were concerned primarily with cost and saw few additional benefits to contractor

involvement: for example, Crow seemed very concerned with minimizing total construction cost. The companies that used early contractor involvement were concerned primarily with budget control and schedule delays and felt that the cost in higher fees was worth the benefits of early contractor involvement: for example, Rouse seemed more concerned with insuring that actual completion deadline be met than with achieving the lowest possible expected construction cost.

	Early contractor involvement	Major concern for structuring project team	Benefits/costs of early contractor involvement
Hines	NO	cost	Few benefits Cost of 2% premium on construction fee
Crow	NO	cost	Little additional benefits Cost of higher construction fee
Linpro	Yes	Budget control	Substantial construct. and value eng. benefits Cost of higher construction fee
Rouse	Yes	Schedule	Benefits of price control Cost is fee paid during design

Figure 12 - Summary of responses

Part IV. A model to evaluate Contractor Involvement Strategies

All this leads us back to the central question of when is early contractor involvement and the team approach most appropriate. In order to answer this question, a model drawing upon all the previous research needs to be developed. This final section attempts to build such a model and begins with a re-examination of the nature of what the benefits of early contractor involvement are and how they occur. This information on the benefits and costs of early contractor involvement is then used to construct a model of early contractor involvement. Finally, attempts at applying the model to the different strategies of project team structure provided by industry illustrate when early contractor involvement is most appropriate.

Understanding the benefits and costs of early contractor involvement

Looking back to the literature, it identified the benefits of early contractor involvement as cost and schedule savings, and budget control. However, it also indicated that there were difficulties in quantifying the benefits of early contractor involvement. This was also confirmed within in the ROPA II example. Tracking potential cost savings is time consuming and verifying the actual implementation is not always possible because of the difficulties of comparing the results with an untested alternative.

In addition, calculating the potential savings due to shorter construction time is extremely difficult. One might attempt to place a dollar value on potential time savings by the resulting reduction in the amount of construction carry interest and labor cost or by evaluating the impact of schedule savings on the financial returns of the project. However, these methods of measuring potential schedule savings face many of the same difficulties as the measurement of cost savings. They are both difficult to track and the actual implementation of them cannot be compared directly with an alternative.

Furthermore, some articles state that early contractor involvement minimizes the possibility that the architect's designs are over budget when bids are completed. However, on an individual project basis it is difficult to determine what the true risks of such a cost overrun would have been and therefore, the value of the contractor's information in reducing risk is also difficult to quantify.

Another difficulty in quantifying the benefits of early involvement is illustrated by the ROPA II structural decision. Minimizing construction cost was not the prime reason cited for the eventual selection of the post-tension garage structure. A combination of aesthetics, schedule savings, and garage efficiency were viewed as the major reasons for the

selection of the concrete garage and steel office structure. The major benefit of early contractor involvement for the owner seemed to come in the form of a more informed decision making process.

The ROPA II example also illustrates the potential for conflicting results depending upon the method of measuring the benefits of early contractor involvement. Using a method of potential time and cost savings, the choice of a structure of concrete and steel would show benefits in terms of the construction schedule. However, using a method that quantified benefits based on actual implementation would indicate that there was very little benefit to the contractor's involvement because the hazardous waste delay negated much of the potential benefits. Furthermore, neither method would adequately encompass the benefits of greater budget control through more informed decisions, and of course neither would capture the benefits of the owner's more informed decision.

It is the intention of this thesis only to examine the difficulties in measuring the benefits of early contractor involvement, not to resolve them. Such work will be left to future research. Nevertheless, even without accurate price comparison methods many owners still believe that early contractor involvement and a team approach are "worth while." While it is difficult to objectively quantify the benefits it

is still useful to develop a model to understand when early contractor involvement is most appropriate. A model explaining the benefits and cost of early contractor involvement would also explain the rationale behind using different project delivery approaches and allow an analysis of decisions about involvement of the contractor.

A model for early contractor involvement

It should be recalled that owners seemed to have two different methods in structuring the project teams. One approach did not use early contractor involvement, the other did. A model that incorporates the benefits and the costs of early contractor involvement can be used to better understand the strategies adopted by the various developers.

Figure 13 illustrates the benefits and costs of early contractor involvement. The horizontal axis represents project time and is divided into three periods: design, construction, and occupancy. The vertical axis represents the expected benefits (at each stage of the project) of a project delivery strategy. Curve AA is meant to represent the benefits from a strategy with early contractor involvement and curve BB is meant to represent the benefits from a strategy without early involvement. The benefits of early contractor involvement result from a combination of potential cost reduction and potential risk reduction. Since no single element, such as construction cost, adequately

encompasses the benefits of early contractor involvement, the axis is meant to incorporate all of the aspects of a project that can be affected by early contractor involvement. However, it must be recognized that early contractor involvement has costs as well as benefits (because the contractor must somehow be paid for early involvement). The increase in costs due to early contractor involvement (compared with the strategy without early involvement) is represented by curve CC in the diagram.

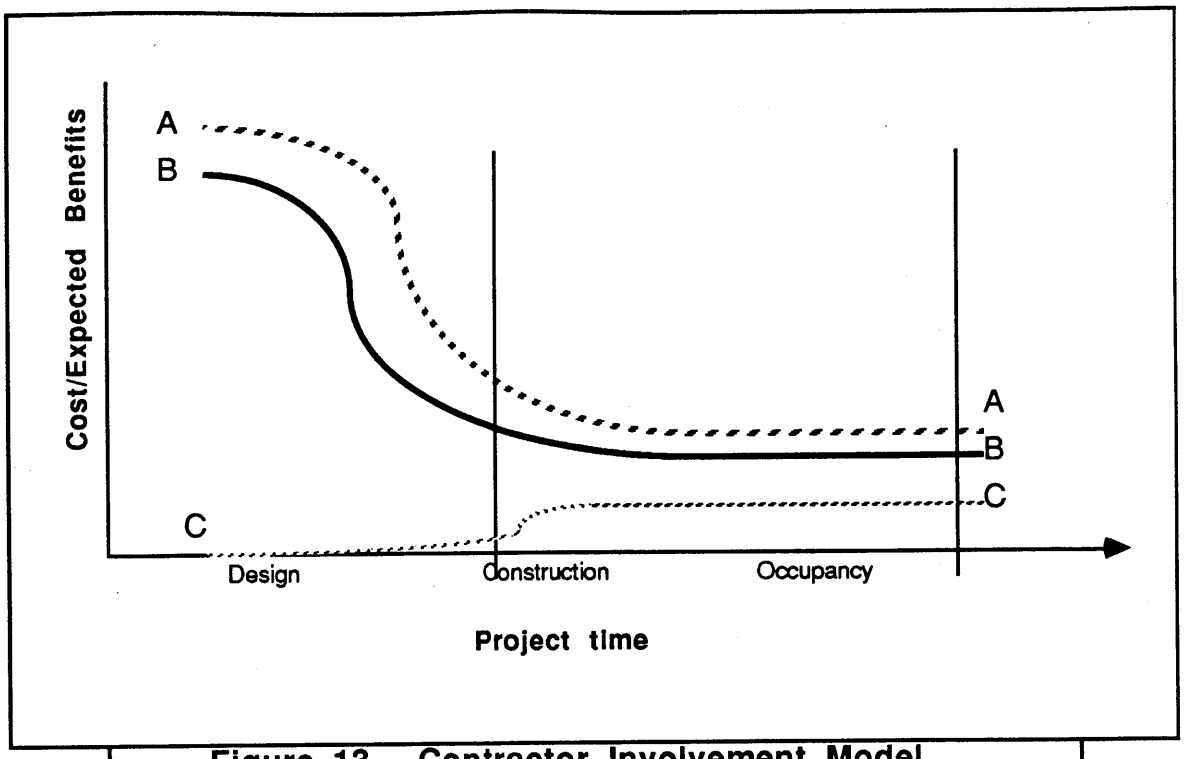


Figure 13 - Contractor Involvement Model

The shape of the curves needs explaining. The AA and BB curves start very high at the design stage, reflecting the fact that the early stages of the project are the places where the design is most flexible, so the benefits of an improved design are highest because it is easiest to implement (according to Paulson, 1976). The expected benefits that can still be realized diminish as more irreversible decisions are implemented and the range of options becomes more restricted. Finally, during the late stages of construction, the potential benefits that could still be realized from some change in the strategy are very small since few decisions can still be changed. The AA curve is above the BB curve through out the design and construction process under the assumption that contractor involvement will always create some benefits. How far the AA curve is above the BB curve is determined by how large the expected benefits of early involvement are: if the benefits of early involvement are small, the AA curve will only be slightly higher than the BB curve, and if they are large it will be much higher.

The shape of the costs curve will depend on the exact method of payment chosen, which varies from project to project. Linpro chose to pay for preconstruction services with higher fees during the construction period, while Rouse chose to pay fees to the contractor during the design period. The costs curve drawn is a typical curve in which the contractor does

not charge much up front for early involvement but then charges an extra fee during construction (2% in the case of Crow). In this case, the extra costs of early involvement are low and increase over time.

To decide whether or not early contractor involvement is worthwhile it is necessary to compare the expected total cost of contractor involvement with the expected total benefit. The total expected cost is given by the area under the curve CC (because this area adds up the cost over all the individual periods). As described above, the total expected *extra* benefit from early contractor involvement is given by the *difference* between the AA and the BB curves. So to determine whether, at the beginning of the project, we should believe that early contractor involvement will be worthwhile we should compare the *area* under curve CC to the distance between curve AA and curve BB at the start of the project.

An example might clarify just how this model works. Consider two projects that are physically identical and which are supposed to be built on the same schedule in different locations. Suppose that members of a firm wish to build one project in a district where it has extensive experience, and know the laws, suppliers, and availability of materials. Suppose that they want to build the other project in a new district that they do not know well. Then the extra benefits of early (local) contractor involvement might be much greater

in the second project than in the first because a local contractor would know many of the pitfalls likely to beset the project in this new location. So even though in terms of physical design and specifications the projects are the same, the AA curve in the second case would be substantially higher than the BB curve indicating the large cost benefits of early contractor involvement.

This model can further illustrate the various strategies for contractor involvement adopted by the various companies interviewed. Reviewing the project delivery approaches within the framework of the developed model provides a better understanding of when using early contractor involvement and the team approach is most appropriate.

Analysis of companies strategies for contractor involvement

Strategies of no early contractor involvement

Without doubt, Hines and Crow believed that the savings reductions achieved with early use of a contractor were not greater than the higher costs associated with a negotiated construction contract. However, both Hines and Crow also adopted strategies that would reduce project costs and risks without using the contractor.

Specifically, Hines relied upon in-house construction expertise to generate constructability, value engineering,

and cost estimation benefits. Implicit in the Hines decision to maintain an in-house staff of experts is that the company incurred the additional cost of the staff's salary. This staff adds to the general overhead under which Hines operates but this additional overhead may be very low on a per project basis because of the volume of construction that Hines conducts. Hines also believes that there are decreased risks during construction because of the use of complete drawings decreases exposure to change orders.

Figure 14 illustrates how the Hines approach compares to the team approach. During design the net benefits of using the in-house consultants raises the expected benefits curve of the project shifting the BB curve up. This occurs because the cost of the in-house consultant is less than the benefits of cost and time savings generated by the consultant making many of the same constructability and value engineering suggestions a contractor might make. The effect of an in-house consultant is to narrow the difference between expected benefits an approach using early contractor involvement over the Hines' approach. In addition, during the construction phase Hines believed the aggressive management techniques of the developer and the use of complete drawings lowered construction costs. This belief that benefits to the Hines approach occur during construction has the effect of shifting the BB curve up during construction as well .

This model explains the rationale for Hines decision not to use early contractor involvement and the team approach. Comparing the Hines approach to the team approach the benefits of the contractor's early involvement are not very substantial. The benefits are less than the cost of the contractor's preconstruction services and thus the benefits do not outweigh the costs.

While Hines used in-house consultants to reduce the potential benefits of early contractor involvement, Crow adopted a strategy of using experienced designers to generate benefits in the design process. While Crow did have in-house expertise available it also chose to pay higher design fees in the belief that the resulting design process would produce results that minimized cost.

Figure 15 compares the approach of Crow to the team approach. Crow believed that there was a net benefit to paying high design fees that would shift the BB curve up during the design phases. Crow also did not believe that early involvement of the contractor in design would result in significant cost savings. This belief could be interpreted to mean that the benefits curve of early contractor involvement AA was not substantially higher than the Crow approach. Thus the potential benefits of using the team approach over the Crow approach were not very great and were

less than the 2% fee during construction that Crow expected would have to be paid for early contractor involvement.

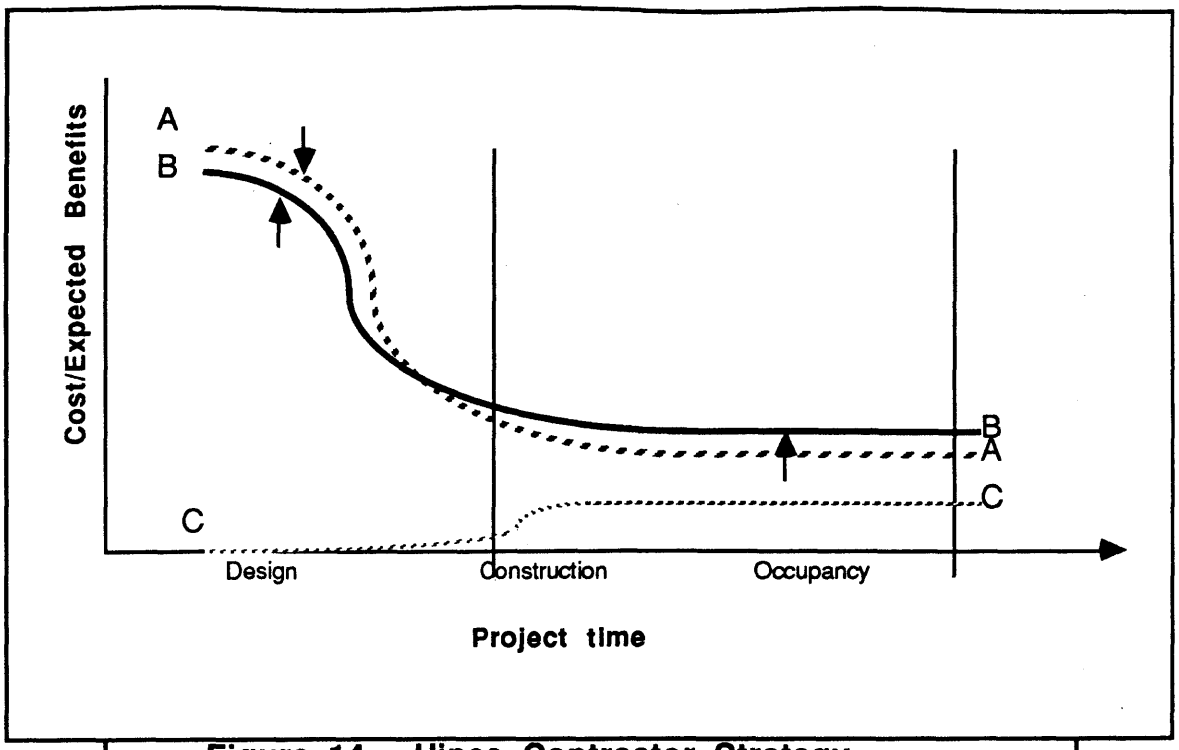


Figure 14 - Hines Contractor Strategy

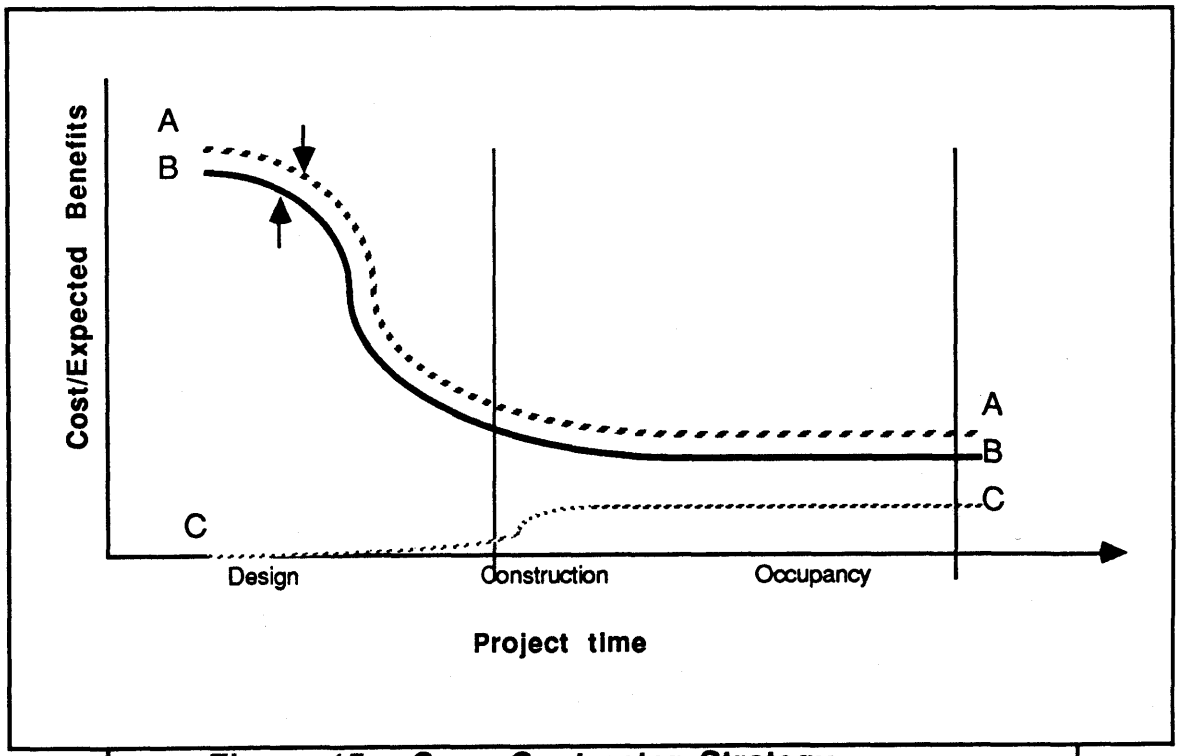


Figure 15 - Crow Contractor Strategy

Strategies of early contractor involvement

By contrast, both Linpro and Rouse believed that the benefits of early contractor involvement were greater than the higher fees paid to the contractor. However, the two companies differed in methods to pay for early contractor involvement. Linpro chose to pay for preconstruction service in the form of higher fees during construction and Rouse chose to pay fees to the contractor during design.

Figure 16 compares the Linpro or team approach to a traditional project delivery approach in which there was no early contractor involvement and the selection of the contractor is competitively bid. Figure 16 illustrates the rational for Linpro's approach to project delivery. Linpro believes that cost reduction and improved quality achieved through pre-construction services produces great benefits in terms of cost and schedule savings and budget control which shift up the BB curve during design. Furthermore, because the contractor provides much of the preconstruction services for a token fee, up-front development cost risks for the owner are also reduced which would also raise the curve still farther.

The cost paid to the contractor in the form of higher construction fees raise the cost curve CC during construction. Nevertheless, Linpro believes that benefits of

early contractor involvement during design more than compensate for the higher fee paid to the contractor in a negotiated contract. Simply put, the benefits of contractor involvement in design outweigh the additional cost during construction.

The rationale for another method of early contractor involvement is illustrated by figure 17. This figure compares the Rouse approach with the traditional approach. Rouse believes, like Linpro, that use of a contractor in design has significant benefits and raises the expected benefits curve BB significantly above the AA curve of no contractor involvement. However unlike Linpro, the cost of early contractor involvement occurs during the design phase and the CC curve is higher during design than construction.

Nevertheless, Rouse believes that the benefits are greater than the fees paid to the contractor during design. And choosing its approach is superior to a more traditional approach of no early contractor involvement.

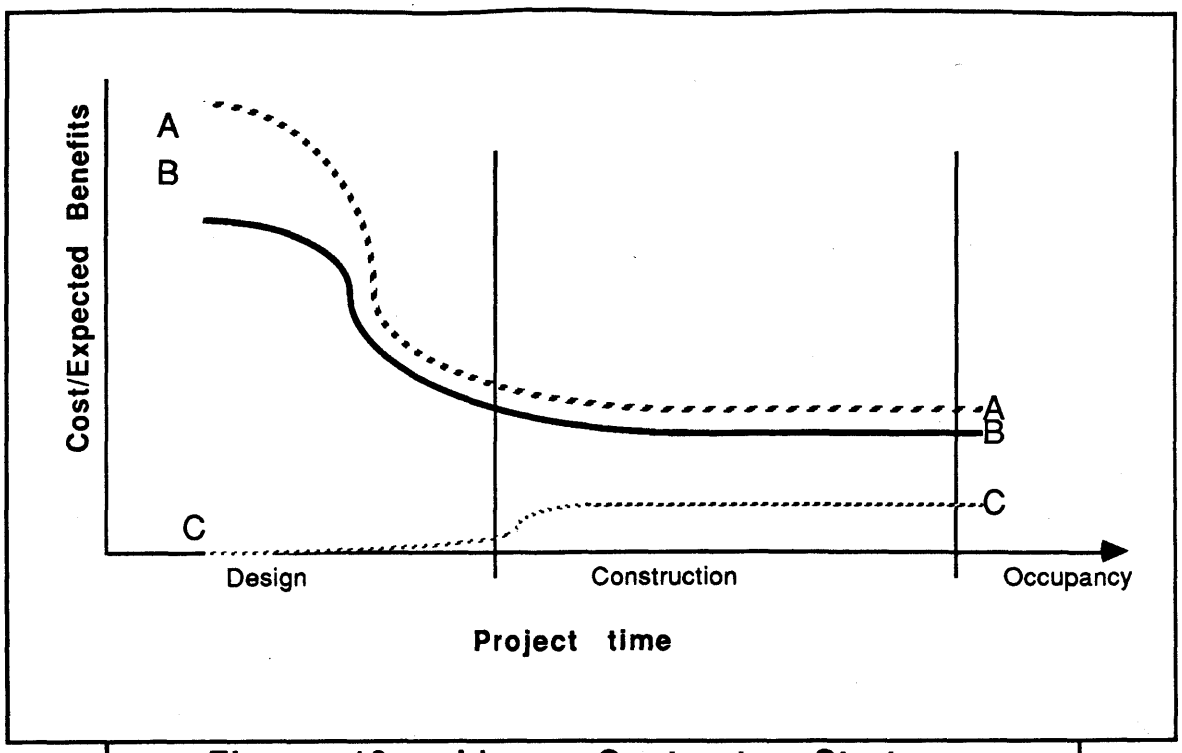


Figure 16 - Linpro Contractor Strategy

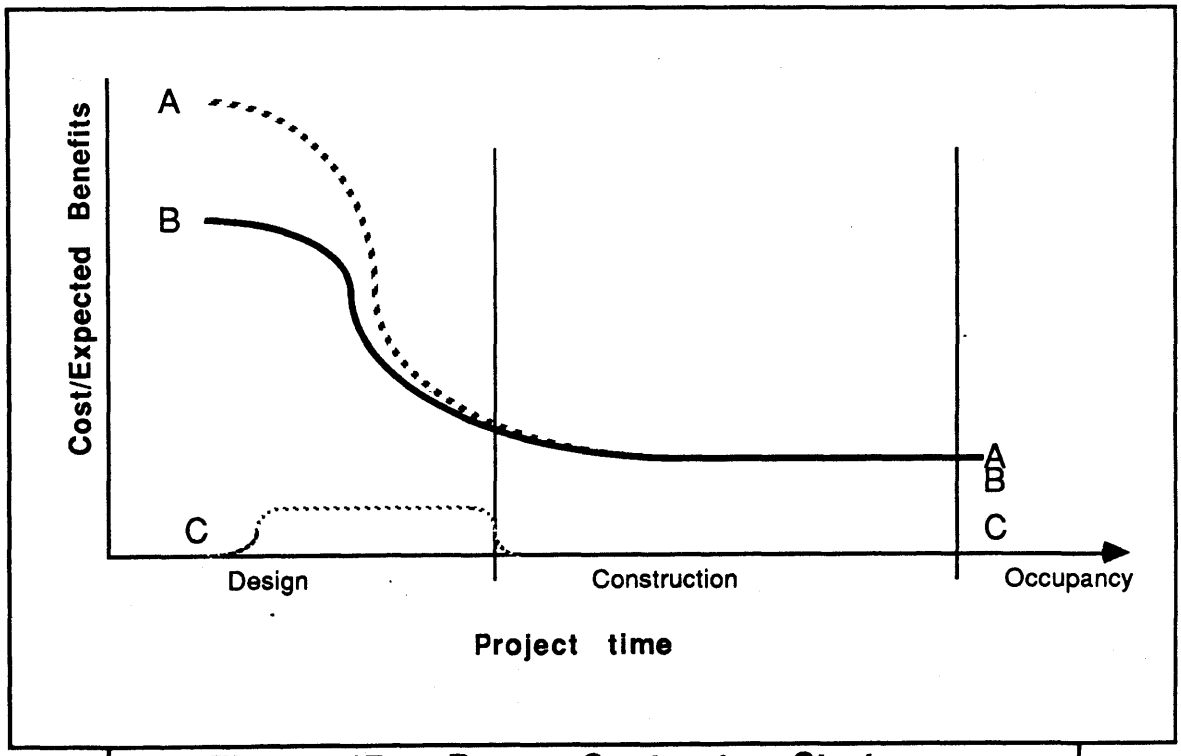


Figure 17 - Rouse Contractor Strategy

Different strategies of early contractor involvement

Looking one step beyond early contractor involvement, it is useful to consider the differences between strategies that use early contractor involvement. Both the Linpro or team approach and the Rouse approach use early contractor involvement but the approaches differed in the way the contractor was compensated for preconstruction services and the way the contractor for construction was selected.

In light of the model, there are two reasons an owner might choose the Linpro approach over the Rouse approach. First, the costs of the team approach could be less than the costs of the Rouse approach, and/or second, the benefits of the team approach are greater than the benefits of the Rouse approach.

The reasons that the costs of the team approach might be less than the costs of the Rouse approach may depend on market conditions in the construction industry. The ability of the owner to get preconstruction services depends on the level of activity of contractors in the market. When construction activity is great, the ability to find a well qualified contractor to provide preconstruction services with no guarantee of getting the job may be difficult. Likewise, when construction activity is slow, contractors may be more willing to offer preconstruction services for very low fees.

One contractor stated that they generally did not offer their preconstruction services to owners unless they intended to sign a construction contract but was willing to take outside jobs when the estimation services had excess capacity. This statement would indicate that in busy times some contractors would prefer not to work under the Rouse approach. With fewer contractors willing to offer preconstruction services this would tend to make using the Rouse approach more difficult.

Furthermore in Denver, a large contractor stated that there were increasingly more instances of contractors' offering preconstruction services without a guarantee of signing a negotiated contract and with understanding that contracts would be competitively bid. The contractor stated that this was due "to the over supply of office space in the office market." He explained that the over supply of office space was resulting in excess capacity in the local construction industry and the excess of "contractors' time has bid down the cost of preconstruction services." In some instances the owners were able to get early contractor involvement during the design phase without paying any fee during design, and with no guarantee that the contractor would receive the construction job.

The second reason that an owner might select the Linpro approach over the Rouse approach is that the benefits of the team approach are greater than the benefits of the Rouse approach. These greater benefits might occur during the design phase or perhaps even during the construction phase.

A specific example during the design phase is how the fee for preconstruction services is paid. In this example the owner's up-front financial risks are lower thereby shifting the expected benefits curve higher during the design phase. The developer, out of his own pocket, pays for services during much of the design phase with the expectation that he will be compensated for much of these costs when a construction loan is taken out. If no construction loan is made then the developer may incur much of the cost of fees paid out during the design phase. Therefore, money spent by the developer early in the project incurs risks because there is the possibility that a construction loan may not be made. Under the team approach the contractor forgoes payment for preconstruction services until after the construction loan is taken out. This is equivalent to the contractor sharing some of the early cost risks of the project. The ability of the owner to share some of the early costs of design work with the contractor, thus may lower the owner's up front financial risk.

In actual practice, not all the early financial risks are truly shared between the contractor and the owner. Most of the owners interviewed stated that if a project did not receive a construction loan, then the owner would still compensate the contractor for costs, but not profit, incurred during design phase. Nevertheless, the contractor is still bearing some of the up-front financial costs involved in the development process.

In addition to benefits during design, there may be greater benefits during construction of using the Linpro approach rather than using the Rouse approach. A major difference between the team approach and the Rouse approach is that under the team approach, there is a continuity of relationships. The same contractor used during design was used during construction. While the literature did not extensively discuss the benefits of early contractor involvement during the construction period, some of the literature on teamwork and communication suggested that there were potential benefits of the team approach in the form of improved communication and trust. Using the same contractor in the project team during design as well as during construction might extend some of these benefits to the construction phase. For example, Fred Wales from G.B.H. Macomber thought that including the field superintendent in the project team meetings of ROPA had benefits. He felt that because the field superintendent was present during many of

the project meetings, he could make better decisions in the field because he had a greater understanding of why previous design decisions had been made.

In sum, determining whether the Linpro approach or the Rouse approach is most appropriate depends on the relative costs of preconstruction fees during design or during construction and the owner's perceived benefits of a Linpro approach over the Rouse approach. When the cost of Linpro approach are less and the benefits greater than the cost and benefits of the Rouse approach the owner would prefer to use the Linpro or team approach.

Summary of model for analyzing early contractor involvement

There is no one best strategy to integrating construction expertise into the design process. However, this thesis provides a model for analyzing the benefits and costs of early contractor involvement. The model provides a framework for owners think about how and when early use of the contractor is most appropriate.

An owner attempting to minimize the potential costs and potential risks of a project might consider using early contractor involvement and the team approach when the potential benefits are greater than the expected cost. For

example, in a highly complex building, like a hospital, where there are a high risks of running over budget and the costs of not meeting occupancy date could be large, this model suggests that such a project would benefit from early contractor involvement. However, in a simple building that is easy to construct, such as a one story building, the early use of the contractor may not result in significant cost savings. Therefore, the benefits of early contractor involvement may not be worth the higher fees paid to the contractor for preconstruction services.

One thing was apparent from interviews with almost all the developers. Their strategies for using the contractor depended greatly on specific project risks and demands. Therefore, this model provides a useful and flexible framework to evaluate strategies for early contractor involvement in the project team.

Conclusion

The intent of this thesis has been to suggest that there are benefits to early contractor involvement and a team approach and to explain how these benefits occur. A model of the benefits and cost of early contractor involvement suggests that early contractor involvement and the use of a team approach is most appropriate when there are opportunities for the contractor to provide benefits during the design process in the form of cost, schedule and budget control.

Indeed, the literature relating to early contractor involvement in design indicates there are benefits in terms constructability and value engineering which can be thought of as also benefits of improved schedule and costs. The literature also describes the emergence of a team approach to project team structure. This team approach is characterized by early contractor involvement, and joint and open meetings throughout the design process. One of the chief benefits of this approach is budget control or increased control of costs during design. Moreover, as we have seen in the example of ROPA II, the manner in which these benefits actually occurs is a complex process.

In any case, a survey of industry practice indicates developers use a variety of project team structures. All the developers interviewed had adopted some strategy to integrate construction expertise into the design process of large commercial development projects. Each developer further believed that its approach was most appropriate for its own company. However, some chose a strategy with early contractor involvement in the project team and others did not.

Using a model developed in this thesis to evaluate the costs and benefits of early contractor involvement provides a framework to better understand these different strategies and

allows one to determine when using a team approach is most appropriate.

When minimizing the construction cost is the only or primary objective of the owner, then early contractor involvement may not be the best approach because inherent in the early use of the contractor are increased costs these preconstruction services will entail. These costs come most tangibly in the form of higher fees during design or construction. In addition, if the project is very simple, then there are fewer opportunities for the contractor involved early in the design process to make substantial constructability or value engineering suggestions. The lack of substantial schedule and cost benefits from early contractor involvement will probably not be greater than the cost and thus early contractor involvement may not be appropriate.

By contrast, if there are issues that are equally important to minimizing cost, such as maintaining a tight control on cost, or reducing the risk of construction delays in a complex project, then the benefits of early contractor involvement may be great enough to offset the additional cost. In these cases, the owner may find early contractor involvement prudent.

Furthermore, depending on how much the owner values such objectives as keeping up-front design costs low, the owner

may prefer to use the team approach to early contractor involvement versus an approach in which all preconstruction service fees are paid during design.

Therefore, in order to apply the model, the owner must carefully think through the value the owner places on the various project objectives and, depending on the ability of early contractor involvement to create benefits in those areas, determine whether early contractor involvement and a team approach is most appropriate.

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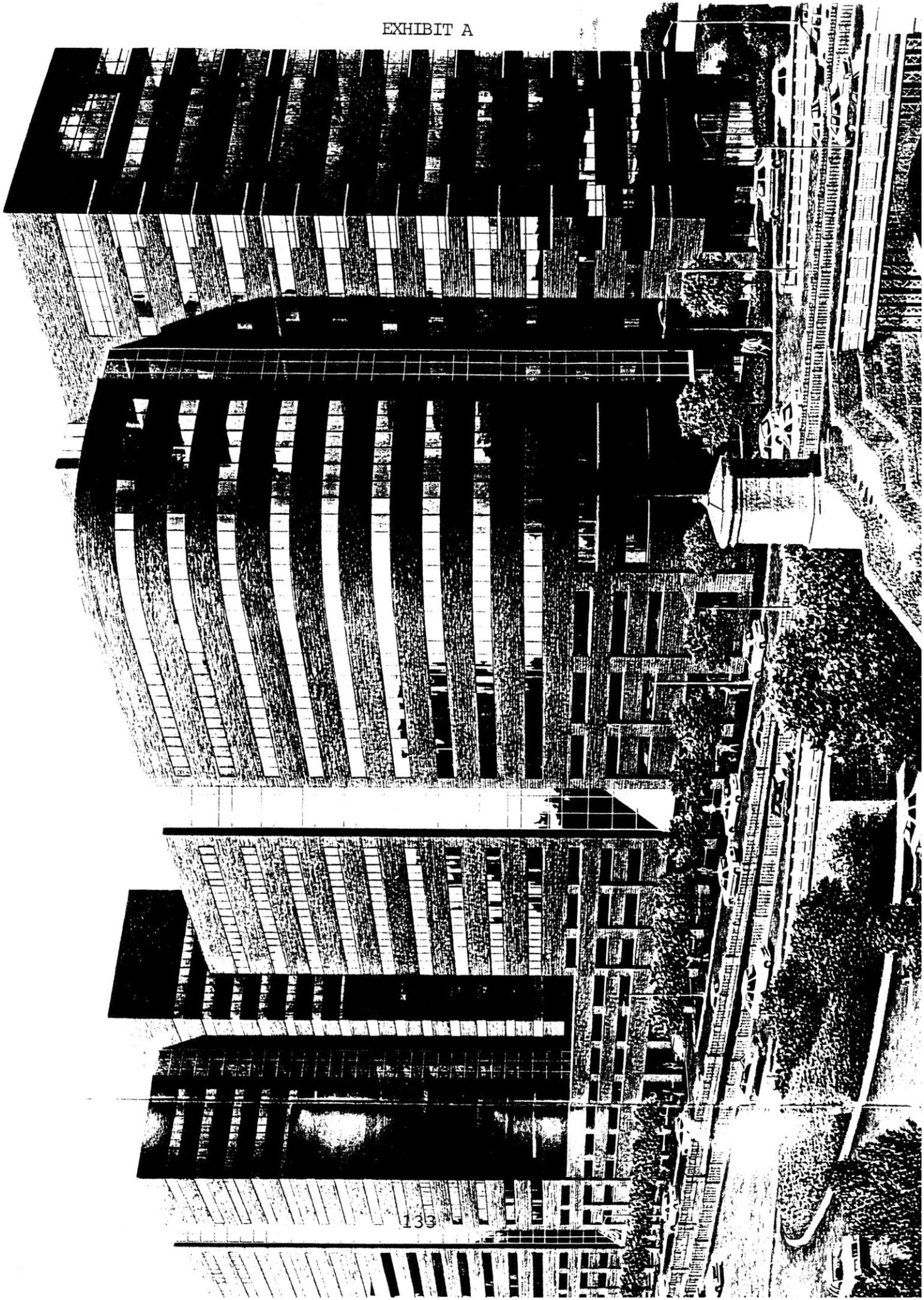
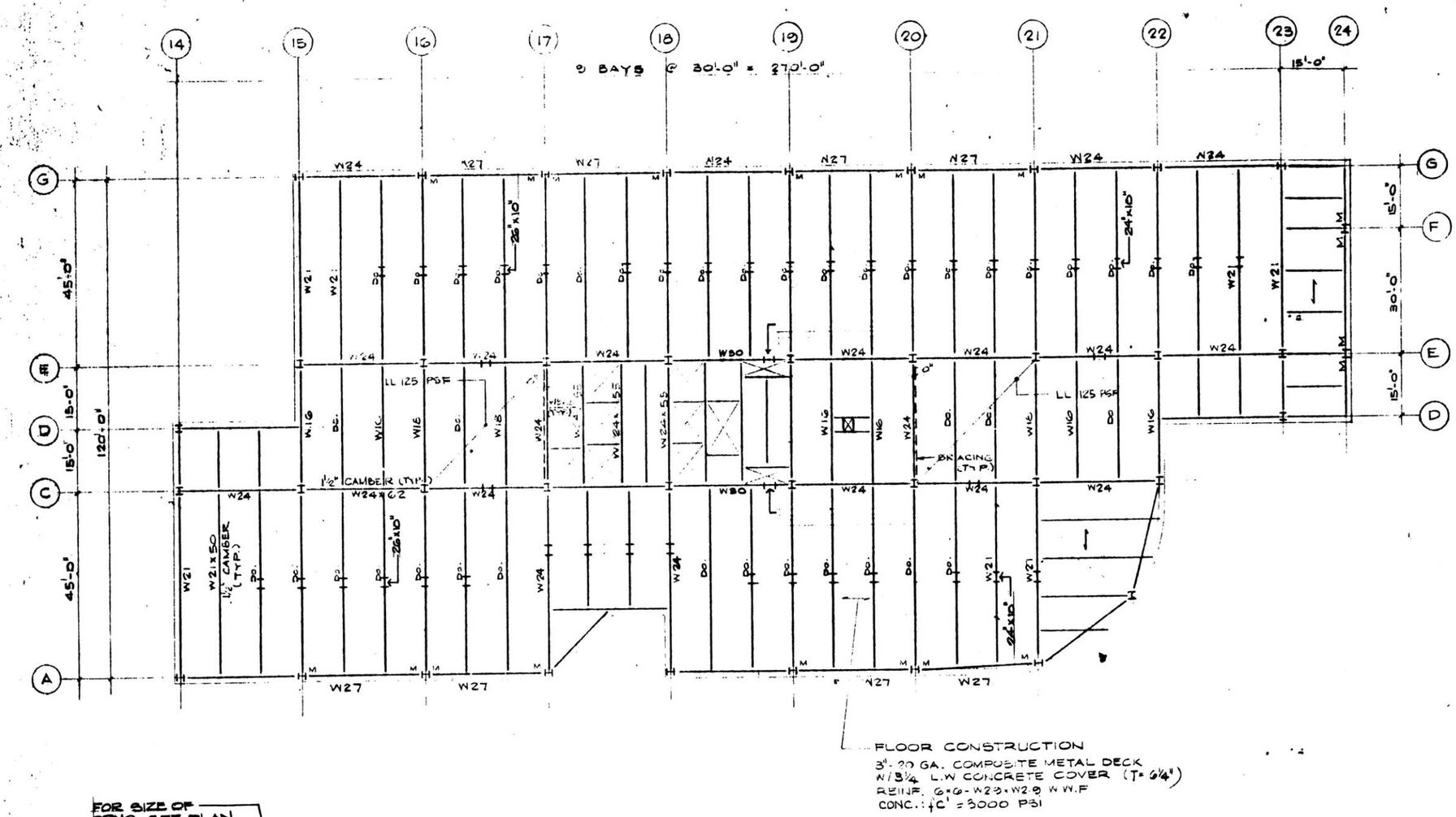
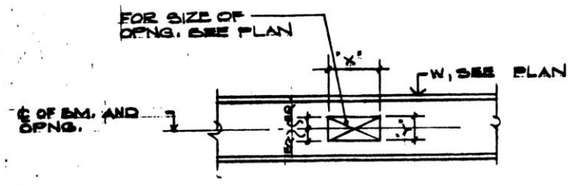
EXHIBIT A





NOTE:
ALL BEAM OPNGS 20" WIDE x 10" UNLESS OTHERWISE NOTED



1 OPENING IN STEEL BEAM.

All structural steel ASTM A572 grade 50

Steel Quantities:	Levels 5 thru RG
Floor Beams:	7.5 lbs/ft²
Columns:	2.5 lbs/ft²
Moment Frames:	3.0 lbs/ft²
Braced Frames:	1.0 lbs/ft²
Miscl. Steel Framing:	0.4 lbs/ft²
TOTAL	= 14.4 lbs/ft²
SHEAR STUDS	= 12 PER 100 SQ/ft

NOTE:

1. All steel quantities include 10% allowance for connections.
2. Misc. steel required for exterior window wall system is not included.

M = INDICATES MOMENT CONNECTIONS.

NO.	DATE	REVISION

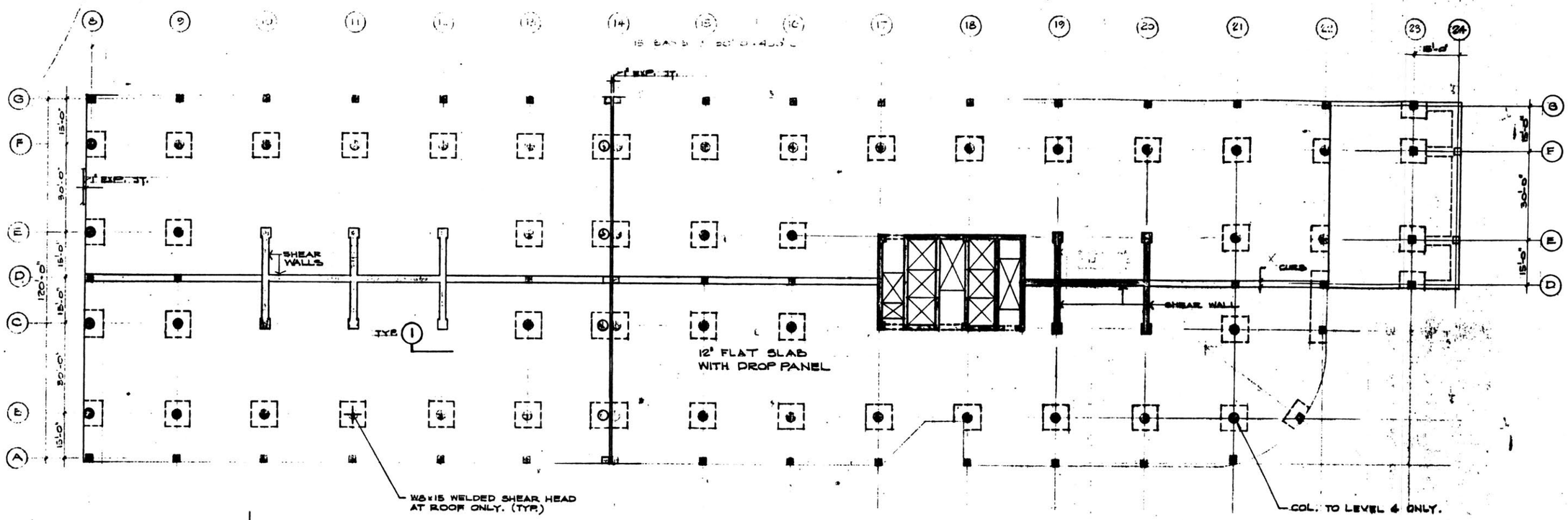
ROPA 2

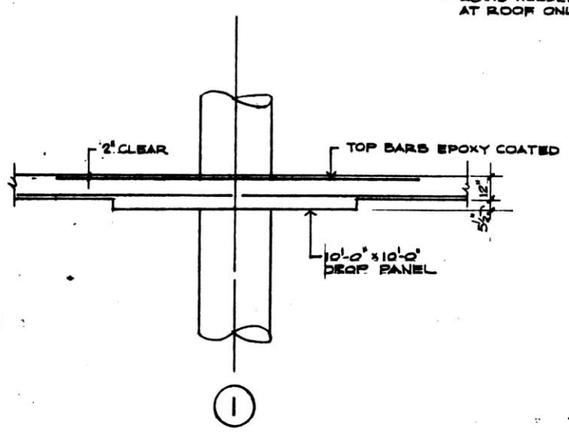
TYP. OFFICE FLOOR FRAMING PLAN - LEVELS 5 TO ROOF

SCHEME A

DATE	SCALE	DRAWN BY	CHECKED BY	DRAWING NO.
9/25/84	1/16" = 1'-0"			SK 1

Weidlinger Associates
CONSULTING ENGINEERS





PARKING AREAS — REINF. CONC. FLAT SLAB W/DROP PANEL SCHEME

COLUMN SCHEDULE - TOWER AREA - LINES 14 TO 24

A. STEEL OFFICE BUILDING
CONCRETE FLAT SLAB IN PARKING

B. CONCRETE OFFICE BUILDING
CONCRETE FLAT SLAB IN PARKING

Location	Size and Reinf.	Floors	Location	Size and Reinf.	Floors
C, E	36"ø 28#14 or 36"x 36"28#11	G.F. to 3rd 3rd to 5th	C,E	36"ø 28#14 or 36"x 36" 28#11	G.F. to 3rd 3rd to 5th
A, G	28"x28" 8#14	G.F. to 5th	A, G	24"x24" 8#11	G.F. to 5th
B,C,F	24"ø 6#10	G.F. to 4th	B, F, D	36"ø 24#11 28"x28" 12#11	G.F. to 5th G.F. to 5th

Shear Walls: 16" thick reinf: #9 @ 12" vert each face
#6 @ 9" horiz. each face

Conc. strength for columns & shear walls: Fc' = 5,000 psi

Slab Reinf: 6.5 lbs/ft^2 all floors

Roof of Parking Area: 8.0 lbs/ft^2.
(lines 8 to 14) Add W8x15 shear heads at Roof Level only

COLUMN SCHEDULE - PARKING AREA ONLY - LINES 8 TO 14

fc' = 4,000 psi

Location	Size & Reinf	Floors
Lines A,D,G	24" x24" 8#10 8#9	G.F. to 2nd 2nd to roof
Lines B,C,E, F	24"ø 12#10 8#10	G.F. to 2nd 2nd to roof

Shearwalls 12" thick #6 @ 12" G. F. to roof
Vert. E.F.
#4 @ 12"
horiz. E.F.

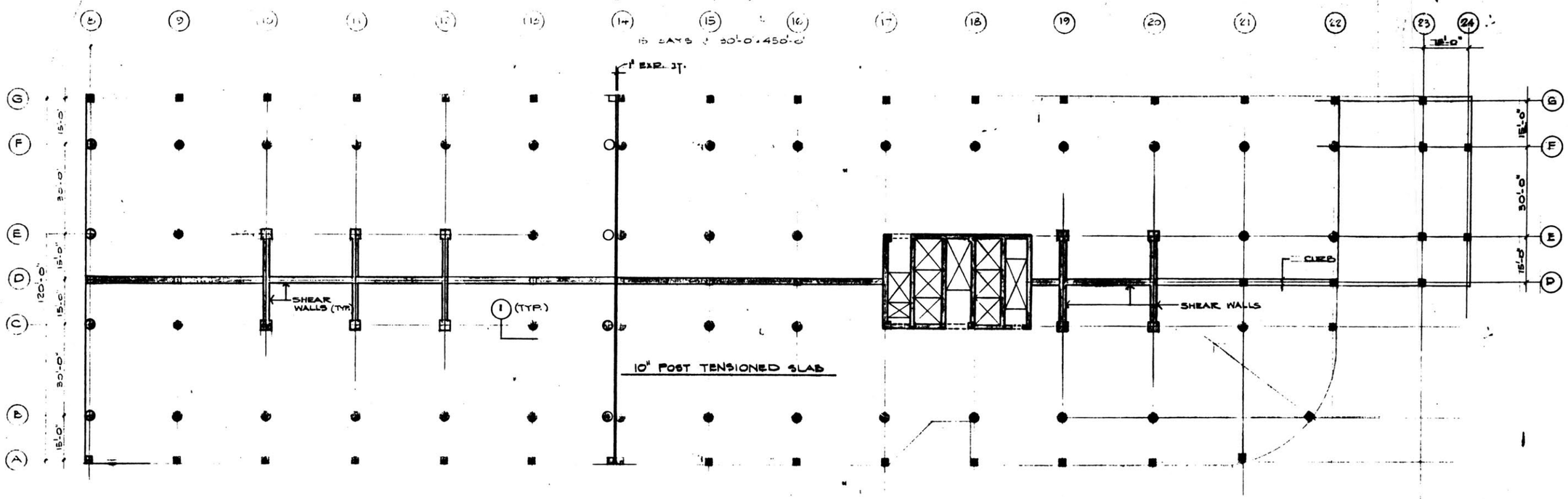
Concrete strength for columns = 5,000 psi
Slabs fc' = 4,000 psi

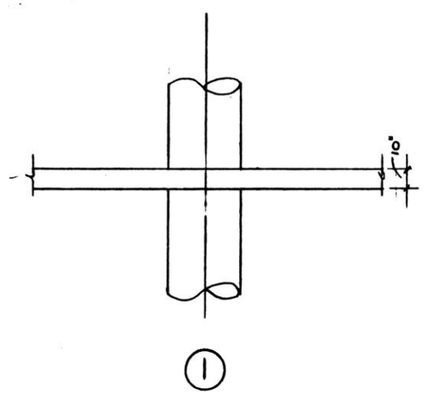
RORA 2
GARAGE LEVELS 2,3 & 4
REINF. CONC. FLAT SLABS
WITH DROP PANELS SCHEME 1.
(SCHEME 1.)

7/18/84 1/8"=1'-0"

Weinlinger Associates

SK-3





POST TENSIONING

1. The requirements for mild steel and prestressing for all post tensioned slabs and beams shall be determined by the Prestressing Contractor in accordance with the design criteria specified.

2. Design Criteria

   a. Design shall be in accordance with the latest addition of ACI 318 and shall conform with the requirements of the State Building Code of the Commonwealth of Massachusetts.

   b. Superimposed gravity loads, unless otherwise noted on the drawings, shall be as follows:

      1) Floor live load — 50 psf
      2) Superimposed dead load — 20 psf
      3) Perimeter wall load — 600 plf

   c. Calculated long term deflection shall not exceed .001 span.

   d. Prestressing shall be designed to allow:

      1) Tensioning when f'ci = 2500 PSI
      2) Immediate removal of forms following tensioning
      3) Simultaneous placement of concrete in adjacent pours
      4) Strands shall be unbonded

   e. See architectural drawings for additional dead load due to curbs and pads.

3. Calculations and shop drawings shall be prepared in a manner suitable for presentation to the Building Official, signed by registered professional engineer and submitted to the Architect for approval by the Engineer of Record.

4. Coordination of structural details of the post-tensioned slabs with walls, columns, railing openings, etc., shall be to the satisfaction of the Architect and Engineer of Record.

5. Post tensioning strands shall be high-tensile, cold-drawn, stress-relieved wires conforming to ASTM A416. Minimum ultimate strength shall be 270 ksf and minimum nominal steel area of strand shall be 0.1531 square inches.

6. Anchoring hardware shall conform to the requirements of ACI 318 and PCI Standard Building Code for Prestressed Concrete.

7. Design shall provide for a minimum compressive prestressing force of 175 psi.

8. Provide a minimum clearance from top of concrete to strands of 2" and a minimum clearance from the bottom of concrete to strands of 3/4".

NOTES:

1. For column schedule and shear walls sizes and reinf; see SK-3
2. Post tensioned slabs shall be designed in accordance with ACI 318-71 using equivalent frame method
3. Min. prestress of 175 psi (approx. 1/2" ø strands @ 15" c/c each way).
4. Provide added reinf. of 1.5 lbs/ft^2, (fy = 60 ksi) in slabs. (approx.)

NO	DATE	REVISIONS

BOPA 2

GARAGE LEVELS

REINF. CONC. POST TENSIONED SLAB WITHOUT DROP PANELS SCHEME #2

DATE	SCALE	DRAWN	CHECKED
7-18-84	1/16" = 1'-0"		

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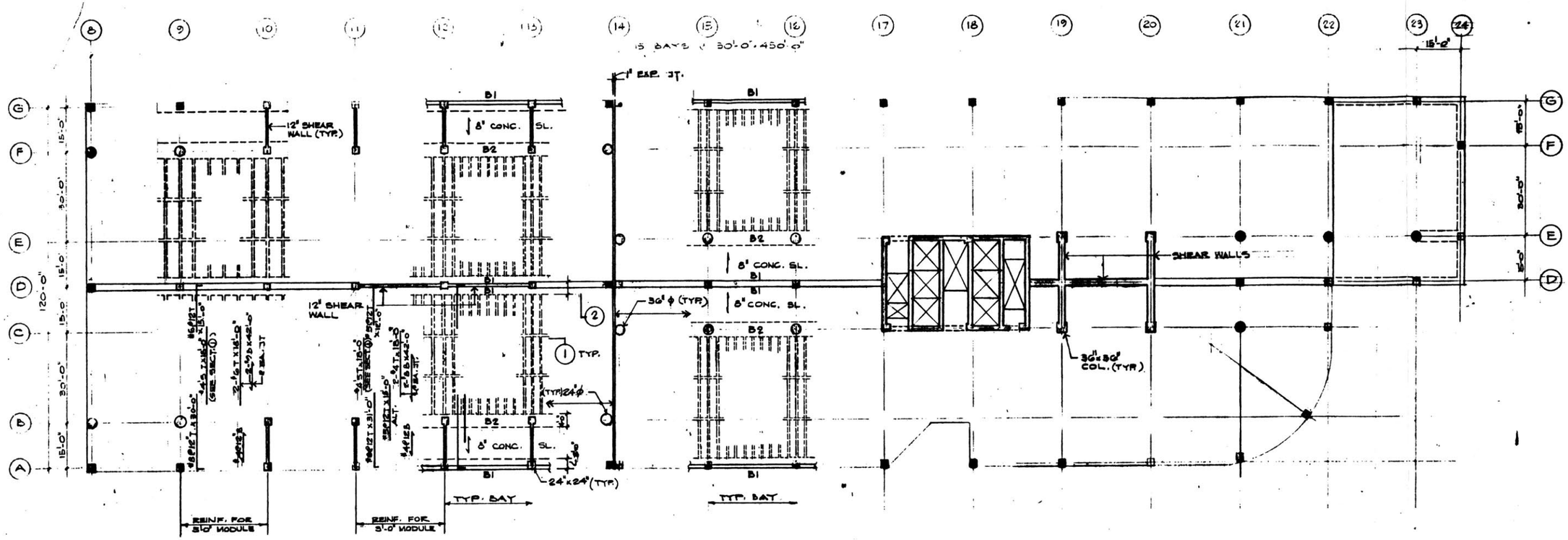
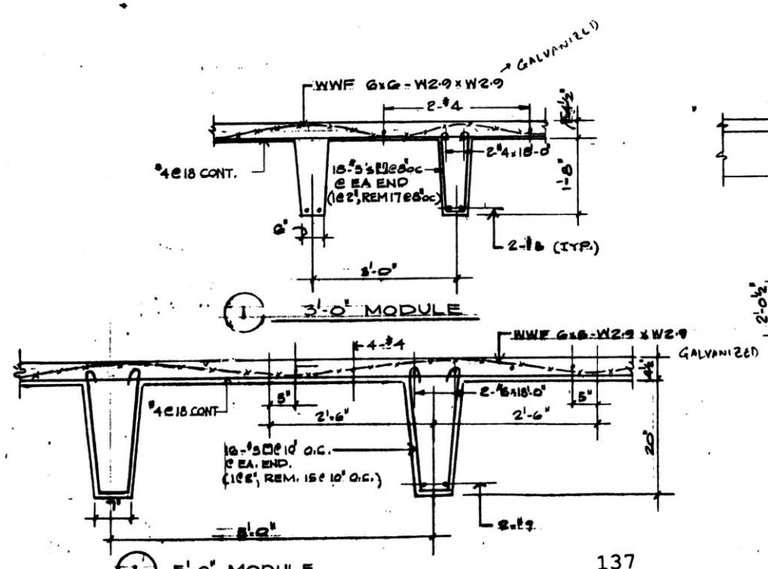
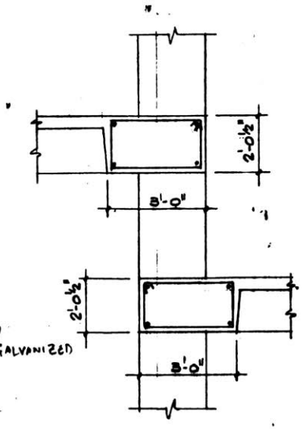
SK-4







COLUMN SCHEDULE - PARKING STRUCTURE - LINES 8 TO 14		
Location	Size and Reinf.	Floors
Lines A,D,G	24"x24" #8#9	G.F. to Roof
Lines B,F	24"#8 #8#9	G.F. to Roof

Conc. fc' = 4,000 psi

COLUMN SCHEDULE - TOWER AREA - LINES 14 TO 24			
A. STEEL OFFICE BLDG. JOISTS IN PARKING			B. CONCRETE OFFICE BLDG. JOIST IN PARKING
Location	Size & Reinf.	Floors	
A, G	28"x28" 12#14 28"x28" 12#11	G.F. to 3rd 3rd to 5th	NOT RECOMMENDED
C, E	or 36"#8 20#14 36x36 20#11	G.F. to 3rd 3rd to 5th	
D	24"x24" #8#9	G.F. to 4th	

Conc: Fc' = 5,000 psi

NOTE:
SEE SK-5 FOR SHEAR WALL SIZES AND REINF.
ALL TOP BARS SHALL BE EPOXY COATED.

NOTES:

Beam Reinforcing			
Beam No.	Size	Reinf.	Stirrups
B1	36" x 24 1/2"	2-#8 T CONT. 4-#7 B CONT.	11-#4 @ 12" O.C. @ EA. END OF BM.
B2	48" x 24 1/2"	12-#7 bot. CONT. #8 T. cont.	11-#4 @ 10" O.C. @ EA. END OF BM.

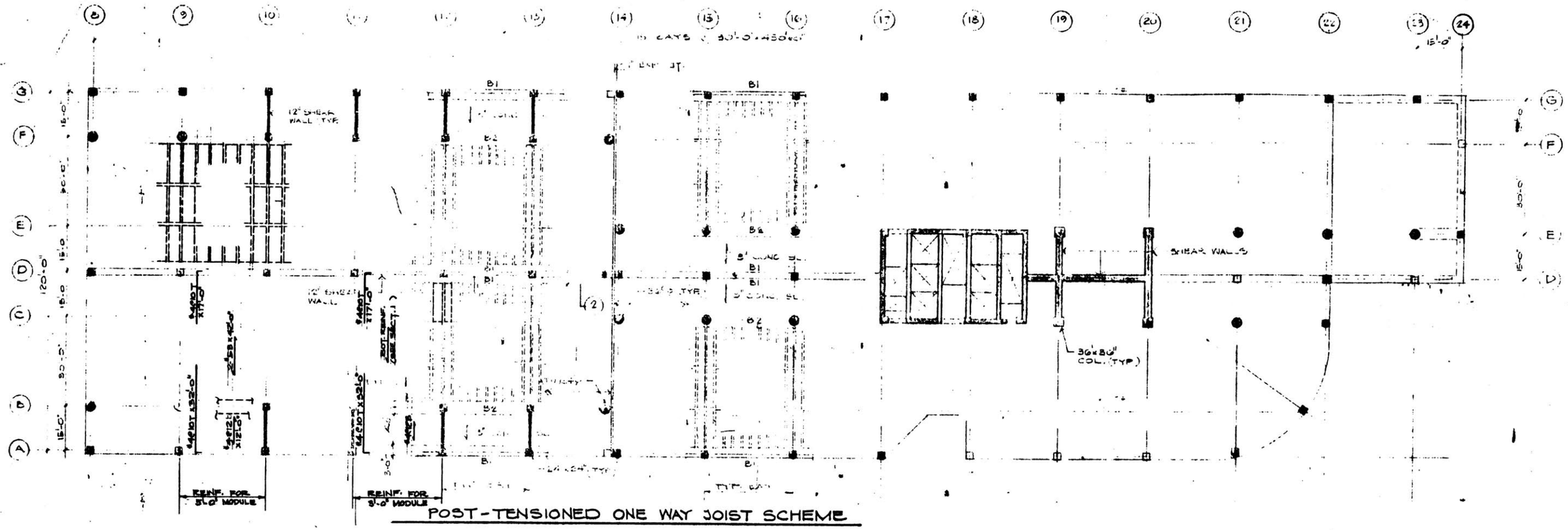
#4's @ 12 FOR REMAINDER OF BEAM.

ROPA 2
GARAGE LEVELS
REINFORCED CONCRETE
ONE WAY JOIST SCHEME

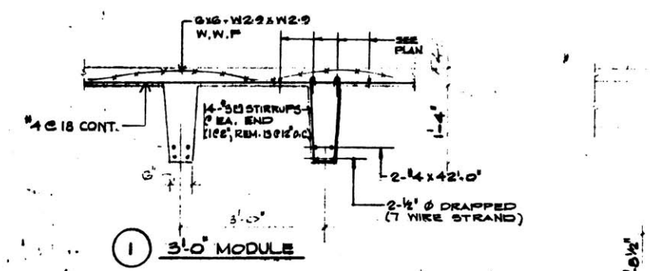
9/25/84 1/16"=1'-0"

Weidlinger Associates

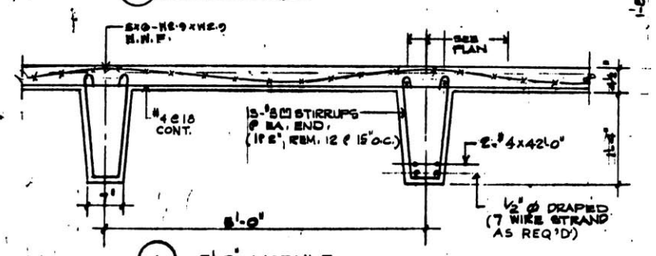
SK-5



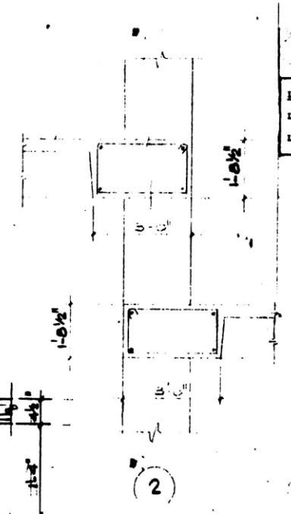
POST-TENSIONED ONE WAY JOIST SCHEME



1 3'-0" MODULE



1 5'-0" MODULE



2

C JOIST SCHEDULE - PARKING STRUCTURE - LINES 8 TO 14

Location	Size and Reinf.	Floors
Line. A,D,G	24"x24" #8	G.F. to Roof
Lines B,F	24"# #8	G.F. to Roof

Conc. fc' = 4,000 psi

COLUMN SCHEDULE - TOWER AREA - LINES 14 TO 24

	A. STEEL OFFICE BLDG. JOISTS IN PARKING			B. CONCRETE OFFICE BLDG. JOIST IN PARKING
Location	Size & Reinf.		Floors	
A, G	28"x28" 28"x28"	12#14 12#11	G.F. to 3rd 3rd to 5th	NOT RECOMMENDED
C, E	36"# or 36x36	28#14 28#11	G.F. to 3rd 3rd to 5th	
D	24"x24"	#8	G.F. to 4th	

Conc: fc' = 5,000 psi

NOTE:

1. SEE SK-3 FOR SHEAR WALL SIZE & REINF.
2. SEE ATTACHED NOTES FOR POST TENSIONED DESIGN CRITERIA.
3. DESIGN LL = 50 PSF
   SDL = 20 PSF
   EXT. WALLS = 500 lbs/ft
4. PROVIDE 2-1/2" Ø STRANDS IN DISTRIBUTION RIB.
5. PROVIDE MIN. REINF. STEEL PER ACI. IN ADDITIO TO REQUIRED POST-TENSIONING STRANDS.
6. ALL TOP BARS SHALL BE EPOXY COATED.

BEAM REINFORCING.

BEAM #	SIZE	REINF.	STIRRUPS
B1	36"x20 1/2"	MIN. REQ'D BY ACI CODE	AS REQ.D
B2	48"x20 1/2"	MIN. REQ'D BY ACI CODE	AS REQ'D

PRESTRESSING STRANDS AS REQ'D.

ROPA 2

GARAGE LEVELS 2, 3.

POST-TENSIONED ONE WAY JOIST SCHEME

9/25/84 | 1/16"=1'-0"

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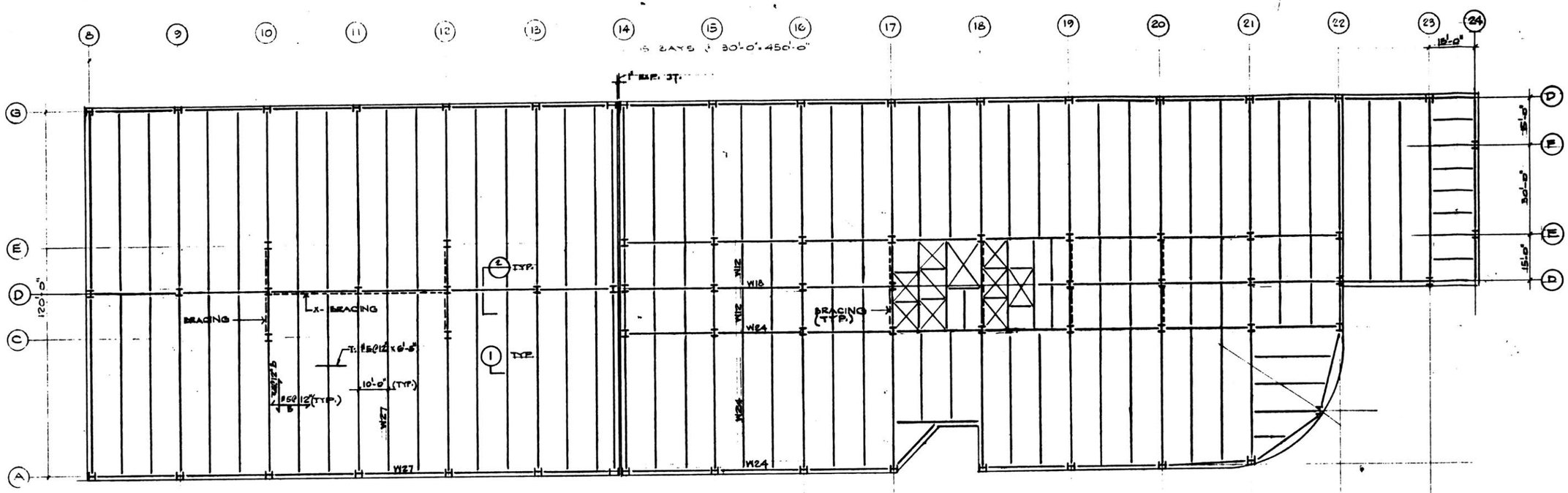
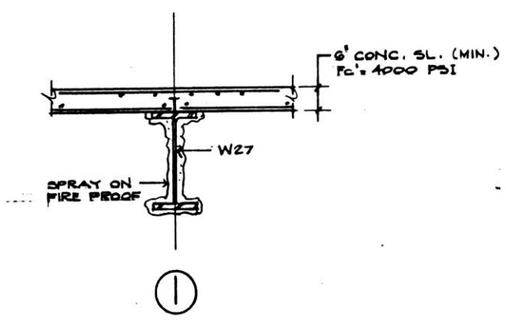
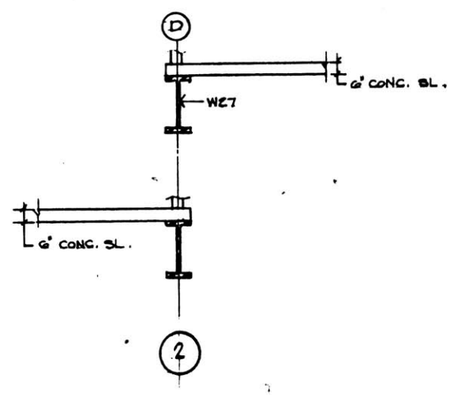
SK-5A







PARKING AREAS LEVELS 2 TO 4
STRUCTURAL STEEL SCHEME

STEEL QUANTITIES - LEVEL 2 TO 4

A. Parking area lines 8 to 14: 16 lbs/ft².

B. Tower area lines 14 to 24: 21 lbs/ft².

C. Shear studs all parking area: 22/100 sq/ft.

D. All steel ASTM A572 Grade 50.

E. PROVIDE AVERAGE 3" ADDITIONAL CONC. ON SLABS FOR DRAINAGE

NO.	DATE	REVISION

ROPA 2

PARKING AREAS LEVELS 2 TO 4
STRUCTURAL STEEL SCHEME

DATE	SCALE	DRAWN BY	CHK'D BY	DRAWING NO.
7-18-84	1/16" = 1'-0"			SK-6

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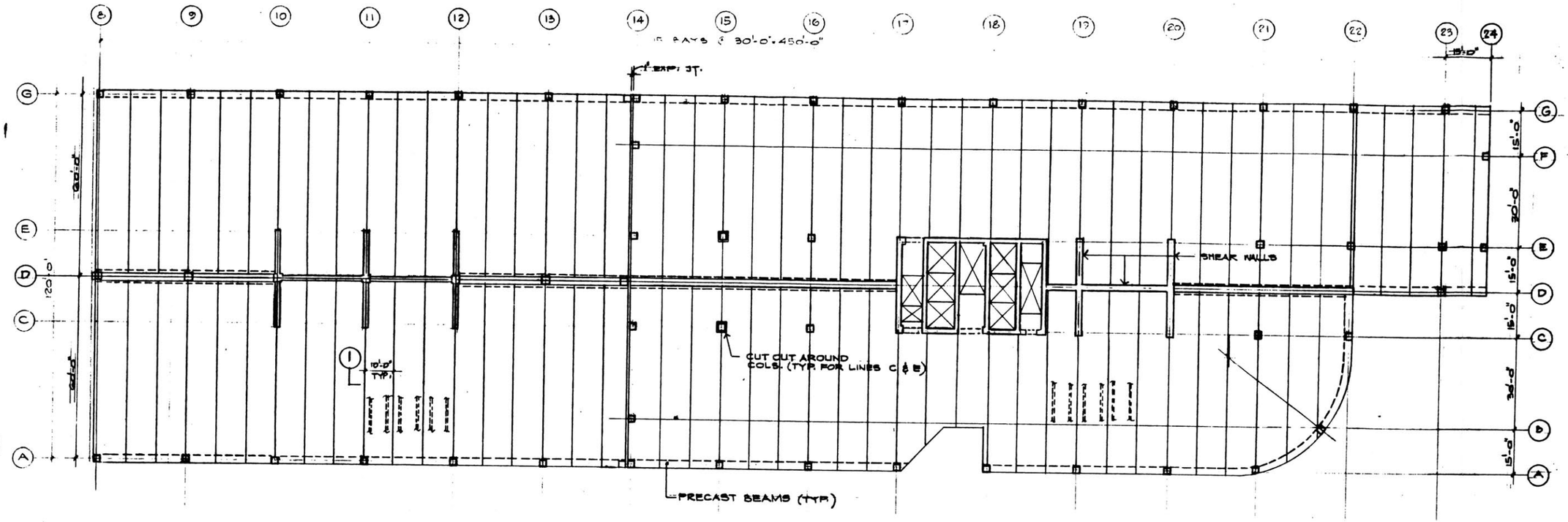

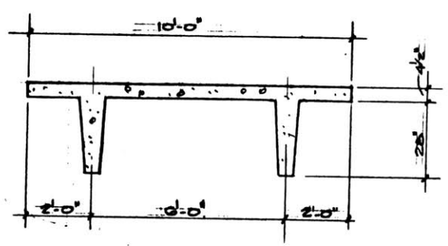

1

NOTE:
CROSS SECTION OF DOUBLE TEES TO BE IN ACCORDANCE WITH THE MANUFACTURERS STANDARD SECTION.

PRECAST DOUBLE TEE SCHEME

DESIGN CRITERIA

1. Precast parking structure for Level 2 through 4 to be designed by precast manufacturer in accordance with the Mass. State Building Code.
2. Provide connections in flanges to transmit seismic loads.
3. All columns shall be cast-in-place concrete.

NOTE:
SEE SK-5 FOR COL. SCHEDULE.

NO	DATE	REVISION

ROPA 2.
PARKING AREAS LEVELS 2 TO 4
PRECAST DOUBLE TEE SCHEME

7-18-84 | 1/16" = 1'-0" | SK-7

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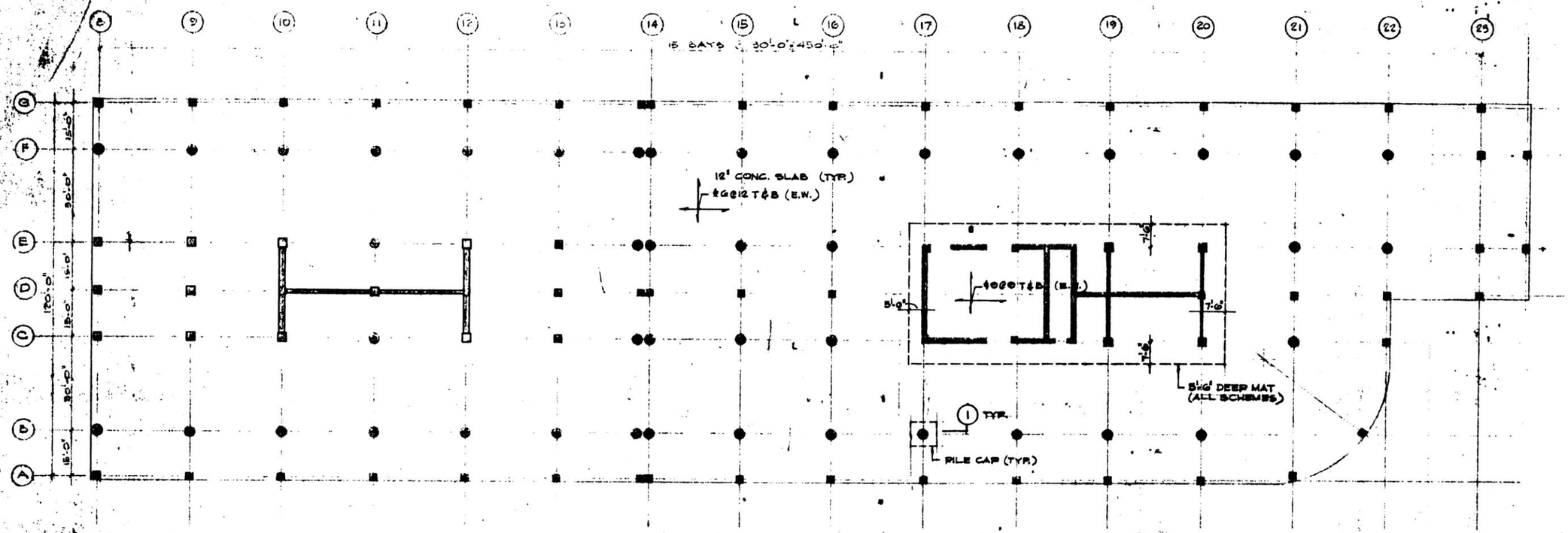

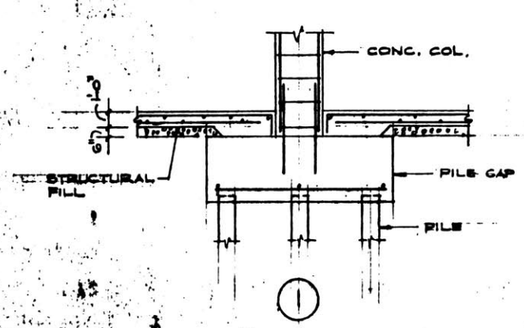

PILE SCHEDULE - TOWER AREA - LINES 14 to 24

Scheme No.	Drwg.	Description	No. of Piles	Avg. Pile Cap Size	Avg. Pile Cap Reinf/Pile Cap
Scheme 1	(SK1 & SK3)	Steel Office Bldg. Reinf. concrete slab for garage	590	(8'-6" x 7'-9" x 4'-0"	500 lbs.
Scheme 2	(SK1 & SK 4)	Steel Office Bldg. Reinf. concrete post tension slab for garage	580	(8'-6" x 7'-9" x 4'-0")	500 lbs.
Scheme 3	(SK2 & SK3)	Conc. Office Bldg. Reinf. concrete flat slab for garage	730	(11'-7" x 7'-9" x 4'-3"	950 lbs
Scheme 4	(SK2 & SK4)	Conc. Office Bldg. Reinf. concrete post tension slab for garage	720	(11'-6" x 7'-9" x 4'-3"	950 lbs.

Note: 1. 5'-6" mat is required for all schemes in core.
2. Assume average pile cap for each column shown on this drawing. outside the mat area.
3. Assume 120 ton precast concrete pile with average length of 85' for comparative pricing purposes.
4. FOR SHEAR WALL SIZES & REINF. SEE RESPECTIVE FRAMING PLANS.
5. ALL CONC. f'c = 4,000 PSI EXCEPT COLUMNS SHALL HAVE f'c = 5,000 PSI.

ROPA 2

FOUNDATION PLAN 1.

(COMBINATION SCHEMES 1 TO 4)

7-18-84 1/8"=1'-0"

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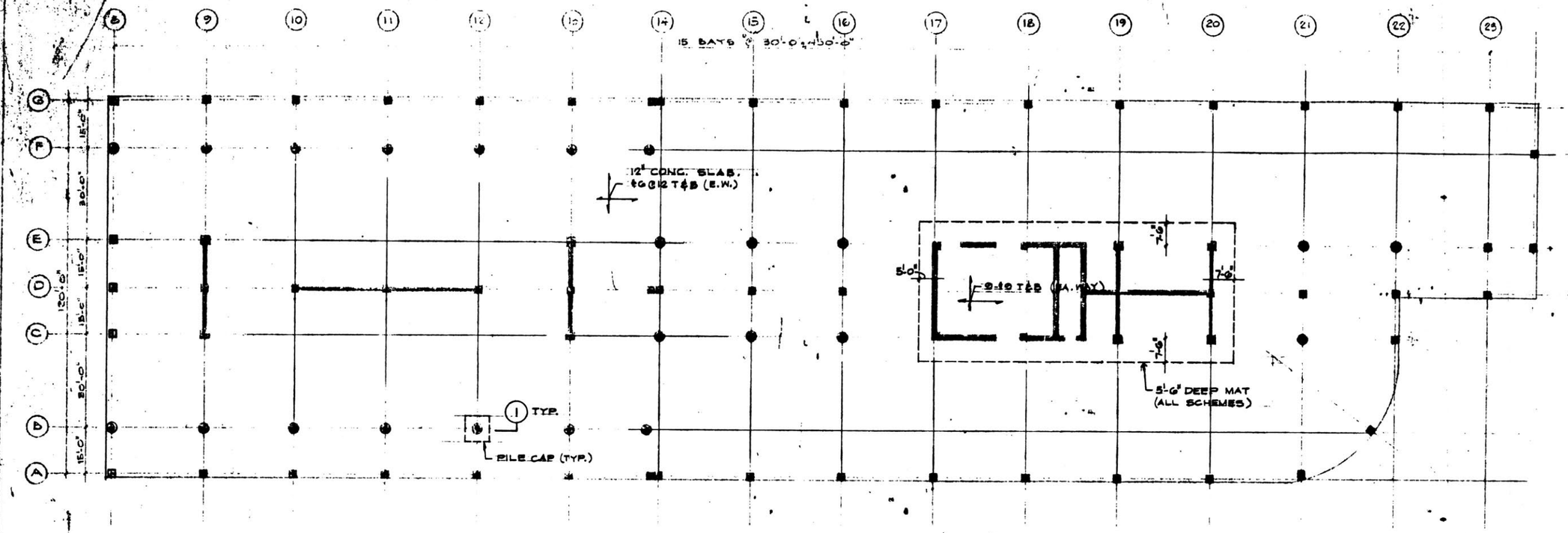
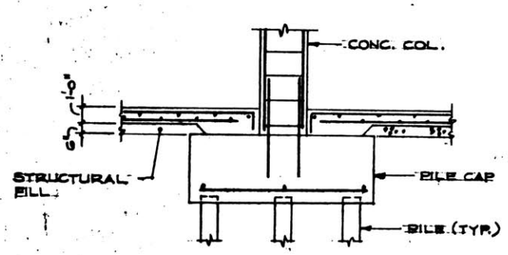
SK-8





1

PILE SCHEDULE - TOWER AREA LINES 8 TO 14

Scheme	Description	No. of Piles	Avg. Pile Cap Size	Avg. Pile Cap Reinf/Pile Cap
Scheme 5 (SK1 & SK5 or SK-5A)	Steel Office Bldg. one way joist for garage	580	(11'-6" x 7'-9" x 4'-3")	950 lbs.
Scheme 6 (SK1 & SK6)	Steel Office Bldg. Steel Garage	540	(8'-6" x 8'-6" x 5'-0"	670 lbs
Scheme 7 (SK1 & SK7)	Steel Office Bldg. Precast Double-T for garage	550	(8'-6" x 8'-6" x 5'-0"	670 lbs.

NOTE: ESTIMATE ONE AVERAGE PILE CAP FOR EACH COLUMN WITHIN TOWER AREA SHOWN OUTSIDE THE MAT AREA.

NOTE:
SEE SK-8 FOR FOUNDATION NOTES

No.	Date	Revision

ROPA 2

FOUNDATION PLAN 2.
(COMBINATION SCHEMES 5 TO 7)

Date	Scale	Drawn By	Checked By	Drawing No.
7-18-84	1/8"=1'-0"			

Weidlinger Associates
CONSULTING ENGINEERS NEW YORK, N.Y. LOS ANGELES, CALIF.

SK9

EXHIBIT C

Cambridge Seven Associates, Inc.

1050 Massachusetts Avenue
Cambridge, Massachusetts 02138
617 492-7000

15 East 26th Street
New York, New York 10010
212 889-4220

MEMORANDUM

DATE: 13 August 1984

TO: Byron Gilchrest

FROM: Ron Baker

PROJECT: Riverfront Office Park (ROPA 2)

SUBJECT: Structural Cost Analysis

On Friday, August 3, Minhaj Kirmani of Weidlinger, Fred Wales, Jimmy Hain, Vinnie Corsini and myself met to review the costs of the seven structural schemes developed by Weidlinger.

A list of Macomber's cost breakdown is enclosed with this memorandum.

Based on this breakdown, Cambridge Seven has made the following conclusions and recommendations:

1. The structural steel scheme is the most economical system for the office floors.

2. The concrete flat slab scheme either with shear heads or post tensioned is the most economical system for the parking garage floors.

   However, this scheme is not recommended as the 15' and 30' structural bays reduce the number of parking spaces by 50 from 669 to 619.

3. The post tensioned one way joist concrete scheme is recommended for the parking garage floors. This scheme has added construction cost of $107,000 ($.64/SF x 167,366 , however, it maintains the number of parking spaces at 669 based on 45' bays.

RB:sb

cc: C. Redmon
M. Kirmani
F. Wales
J. Hain

Enclosure