SLIPFORMING IBM TOWER

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ABSTRACT: The IBM Tower in Atlanta, Georgia, is an extraordinary construction project with fascinating architectural, engineering, and construction innovation and practice. The building was constructed using a concrete slipform core with structured steel floor framing, composite exterior columns, and granite skin with insulated gray tinted glass. A team approach has resulted in a maximum amount of quality construction being accomplished in minimum time, and the project being completed within a tightly controlled schedule. A three-phase value engineering study was conducted for this project. In Phase I, eleven floor framing systems and eight wind framing systems (which in combinations gave forty-two possible schemes for the structure) were developed. In Phase II, pricing information of structural steel was developed. In Phase III, a typical floor and columns, and wind-resisting elements for the entire height were designed. Using this information, the unit cost of structure and the total construction time were estimated. This paper provides an overview of the IBM Tower, value engineering results, and slipformed core construction used in this project.

INTRODUCTION

The IBM Tower at Atlantic Center, located in Atlanta, Georgia, is a massive construction project and one of the ten tallest structures currently being built in the world. The Atlantic Center is a phased construction project that will take from 5 to 8 yr to complete. The full project includes a 50-story IBM Tower and parking garage, three future 20-story towers, and two future parking garages, as shown in Fig. 1. The tower and parking garage architecture is "postmodern," using a great deal of granite exterior and high marble arches at the ground entrance (Platten 1986). The tower's roof is a 130-ft (39.62-m) copper pyramid topped by a cupola, as shown in Fig. 2. The final height of the structure will be 820 ft (250 m) from ground elevation. The tower, which is 50 floors at 13 ft (3.96 m) from floor to floor, provides a total of 1,100,000 sq ft (102,193 m^2) of office space. The ground floor, which is two stories of 30 ft (9.14 m) height, will be leased to service tenants, who will provide a multitude of services to the building's office-space tenants. Floors 3–29 will be occupied by IBM, and the remainder of the building will be rented to other tenants.

The parking garage, which includes a post-tension parking deck, provides space for 2,375 cars. Its structure comprises 11 levels, 30 ft (9.14 m) vertical height below grade and 70 ft (21.34 m) above grade. Fig. 3 shows

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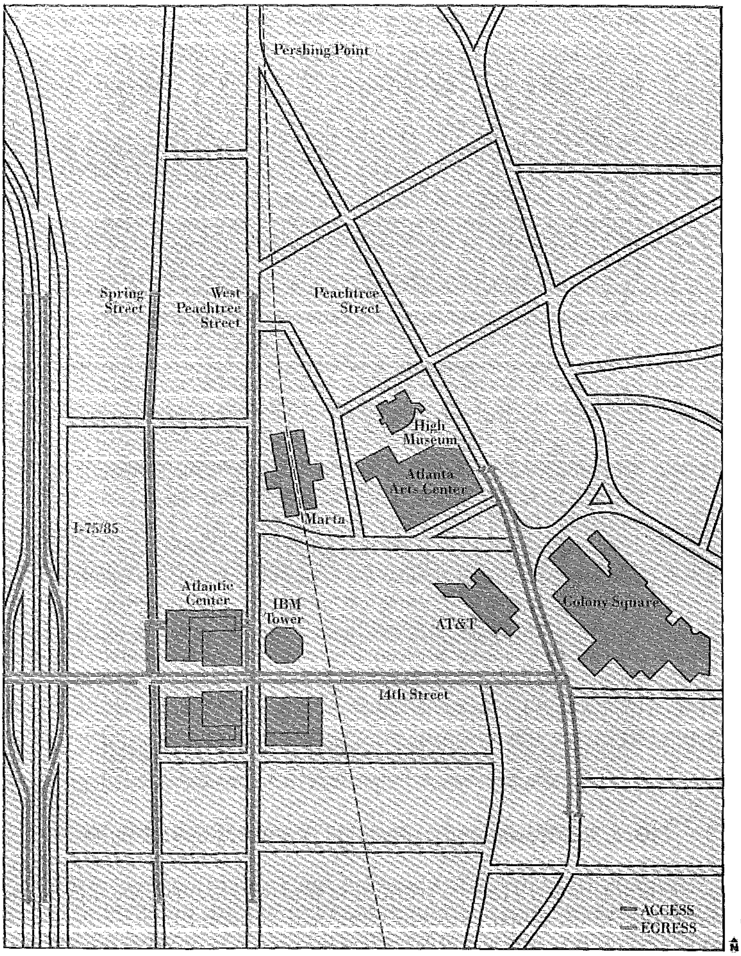

FIG. 1. Location of IBM Tower in Midtown Atlanta

an overview of the tower and parking garage in front. All phases of the project, when completed, will provide 2,500,000 sq ft (232,258 m^2) of office space ("Project" 1986).

Entrances to the tower on four sides are marked by monumental 55 ft (16.76 m) granite arches. The building features a series of setbacks on the tower facade and is topped by an octagonal copper pyramid ("Pyramid" 1986). At street-level, granite-paved plazas frame the building on all four sides. A 2.5-acre (1 = ha) park is planned adjacent to the tower as an extension of Peachtree Walk Park. Atlantic Center has been designed to serve as the focal point of the midtown business district.

The project is jointly owned by Cadillac Fairview Urban Development Corporation and IBM Corp. The project was designed by John Burgee and Philip Johnson, and the current and first phase of the project is being constructed by Henry C. Beck (HCB) Contractors and some 42 subcon-

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FIG. 2. IBM Tower and Installation of Cupola by Helicopter

tractors. Atlanta-based Heery Architects and Engineers, Inc., is associate architect; and Sundt Corp. was the slipform contractor.

Project Life Cycle

Design plans were unveiled in May 1985, and site preparation and demolition work started in October 1985. The first construction phase began in January 1986, and was completed in *February 1988*. This fast-paced, 25-mo total duration for the first phase is due to many of the innovatons accomplished by the engineering, design, and construction team. A further scheduling factor complicating the construction project was that on October 1, 1987, IBM personnel needed to move into the tower at a rate of 3 floors every 2 weeks. This meant that 5 mo of construction was ongoing while the building was partially occupied.

Planning Phase

The planning phase for the construction began approximately 2 yr prior to the groundbreaking. The construction management team was brought in very early during the planning phase and has worked very closely with the owner and the design team throughout the entire project. A great deal of

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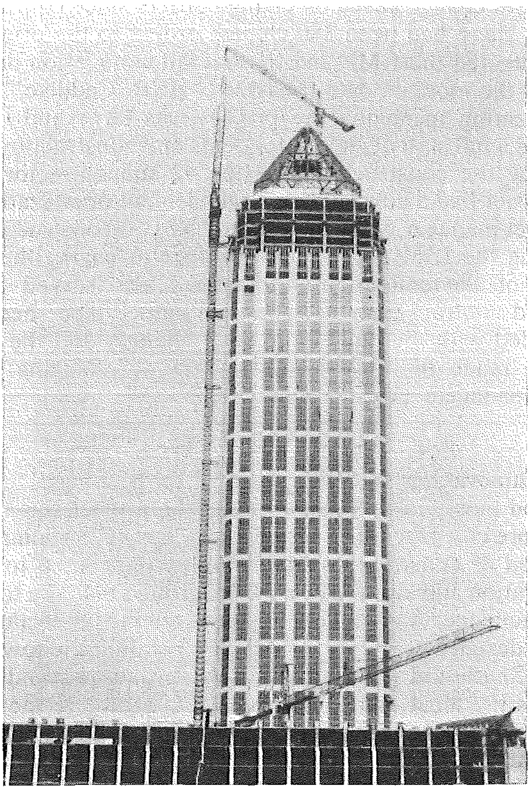

FIG. 3. IBM Tower and Parking Garage in Front

value engineering was undertaken pertaining to much of the construction scope, which included the second-tallest slipform core in the United States and composite structural steel and composite exterior columns (Tuchman 1986).

Construction Phase

Immediately after construction began in January 1986, the owner announced some changes in the design of the tower that included some architectural changes and added six additional floors to the structure's height. These and subsequent changes have lengthened the total duration of the contract. However, the October 1, 1987, tenant move-in date for IBM office spaces did not change since construction started. This factor contributed significantly to the fast pace of construction.

The contract between HCB and Cadillac Fairview was a cost-plus-fixed-fee contract with HCB sharing savings below the guaranteed maximum price (GMP) at a rate of 25%, with 75% going to the owner. When construction started, the designers provided HCB with 80% of the structural design drawings and 60% of the architectural drawings, and an interim guaranteed price was negotiated based on that set of drawings. When the final drawings were completed, a final GMP was negotiated and has continued to change based on change orders since contract award. As of April 1987, there had been 380 change orders to the original contract. These have affected the GMP and the overall completion date; however, none changed the move-in date for IBM (''HCB, Cadillac'' 1986).

The organization managing the project was large and complex. The contractor had a full staff of superintendents and construction managers on site to manage the construction and the 42 subcontractors (''General'' 1986). The owner had a construction management organization headed by a senior project manager who was assisted by two construction managers, one overseeing the IBM floors and the other managing the other tenant floors. Each of the construction managers was served by a staff of inspectors and contract administrative personnel. The sheer size of this project, coupled with the huge number of changes and the unique architecture, have made the IBM Tower a very challenging job from the construction management standpoint.

Construction Innovations and Difficulties

The first and most visible innovation on the project was the 725 ft (221 m) slipform core constructed by Sundt Corp. during the summer and fall of 1986. Its speed of construction significantly contributed to the project's shortened duration and allowed steel work around the core to begin sooner in the work sequence. A great deal of study, testing, and value engineering went into the design of the core, which carries all of the tower wind loads (Smith 1986; Smith and Pinkney 1987). According to Sundt officials, the IBM core was the most complicated slipform structure the company has ever built, primarily due to its structural design. The form moved at a rate of approximately one floor per day, and upon completion was within 1.5 in. (3.81 cm) of plumb. After the slipforming operation was complete, the three-level form was dismantled and removed from the structure piece by piece.

Another visible feature of the project is the pyramid roof, which is 130 ft (39.62 m) tall and extends about 100 ft (30.48 m) above the core, as shown in Fig. 4. The height of the roof and the detailed architectural materials and requirements made this phase of work extremely difficult.

The composite exterior columns, as shown in Figs. 4 and 5, are another construction innovation. The exterior columns minimize column intrusions in the lower 25 floors of office space and keep lease space totally column-free in the upper 25 floors. The columns are reinforced concrete poured around steel ''I'' beams. They are insulated and then covered with a granite exterior. The insulation was installed to minimize differential thermal expansion between the exterior columns and the core. The composite columns also minimize the differential creep and shrinkage between the core and the perimeter of the building floors. In addition, floors were constructed to slope from 0.25–1.25 in. (6.4–31.8 mm) from the core to the perimeter to minimize further the effect of the core settling less than the exterior perimeter of the building.

Another construction management problem the managers on-site faced was the construction of the underground tunnel between the parking deck and the tower. The tunnel crosses under West Peachtree Street, which is a Georgia State Highway as well as an Atlanta thoroughfare. This required

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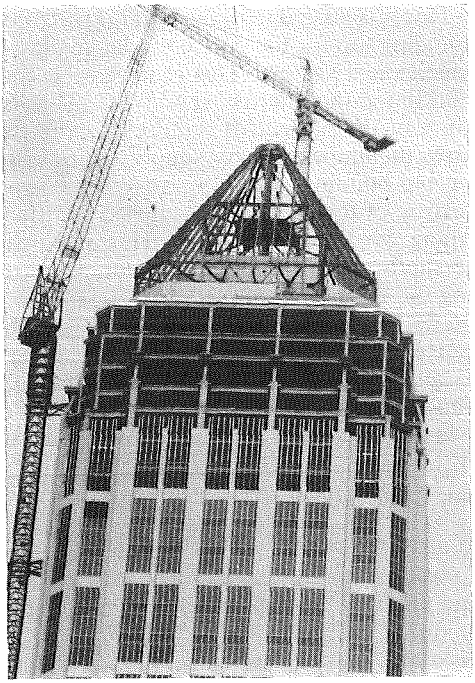

FIG. 4. Construction of Pyramid in IBM Tower

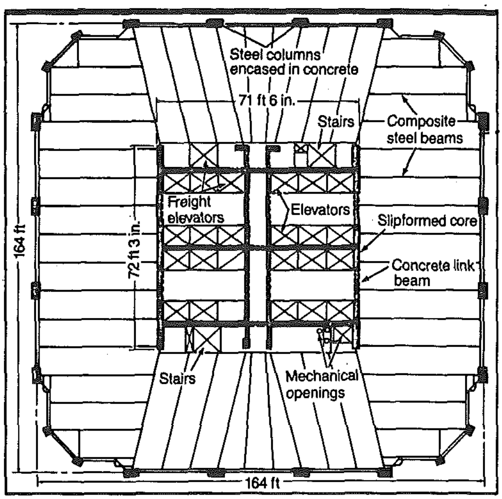

FIG. 5. Link Beams Shown in Typical Framing Hold Half of Core's Rebar

complex coordination between the contractor, the owner, and the relevant governing bodies.

Since the IBM Tower is roofed with the pyramid architecture, there is no location on the building top for the conventional cooling tower needed for the structure's mechanical system. This required the cooling tower to be located in the parking garage across the street. This is another unique construction feature of the project. It requires a more extensive mechanical system and uses the tunnel to carry supply and return lines to and from the cooling tower and building.

A site characteristic of the project that caused additional challenge was the strong prevailing wind from the west. This significantly affected the "steering" of the slipform during core construction as well as the pouring of concrete during the entire project.

The unique and detailed architecture of the project, which incorporated five different imported marbles and imported granite from Spain, Italy, and Morocco, added an international dimension to the job. This required extensive coordination. Some architectural decisions were made late in the construction phase and therefore delayed material delivery.

Slipformed Core Construction

The concrete core of the IBM Tower is built by slipforming. The project is the tallest slipformed concrete building core ever constructed in the United States, and possibly the world. As shown in Fig. 6, the core is the structural "backbone" for the 50-story IBM Tower. The core contains space for the elevators, elevator machinery, stairways, rest rooms, and vertical chases for mechanical and electrical systems, as shown in Fig. 7. The 725 ft (221 m) high core cost approximately $4,500,000 and takes all the wind loads for the 50-story building.

Slipforming is a method of rapidly forming and placing concrete using hydraulic jacking units to raise a custom-made form at a vertical rate of approximately one floor per day. Slipforming building cores and silos—round, square, and rectangular—is one of the specialties of Tucson, Arizona-based Sundt Corp. To date, the firm has slipformed 27 silos and cores for projects throughout the country.

Slipforming's principal advantage is speed. On the IBM Tower project, the time from commencement of "slipping" to topping-out of the core was just 57 workdays. Conventional construction methods would have required an estimated 178–270 workdays to complete.

A concrete core's benefits to a high-rise building are many, including structural stiffness, oscillation damping, and fire resistance. Depending on the seismic risk and wind loading, the core can be designed to meet most or all of the anticipated lateral loads, which reduces the complexity and cost of structural steel connections. In most cases, the core also carries all of the interior vertical loads, but interior steel columns may be necessary in very large floor plans (Henry and Parsons 1982).

The decision to use a slipformed core must be made by the structural engineer early in the design phase of a project. On the IBM Tower, the general contractor recommended a slipformed concrete core after studying 42 different combinations of floor-framing and wind-framing systems. This analysis, made in association with the project's structural engineer, the

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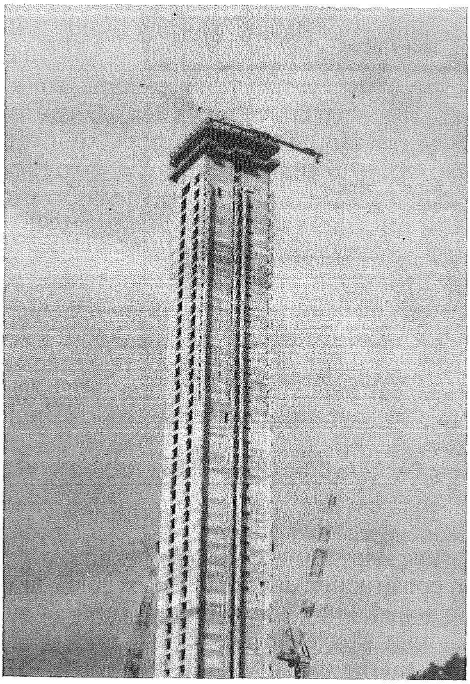

FIG. 6. Overview of Concrete Core and Steel Framing in IBM Tower

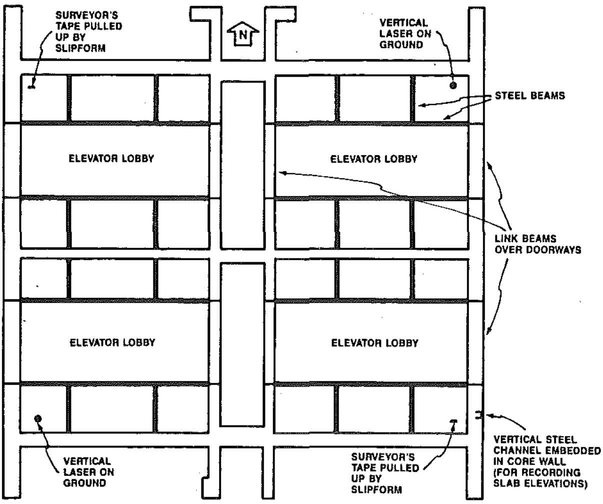

FIG. 7. Four Shafts of Building Core (Courtesy of Concrete Construction)

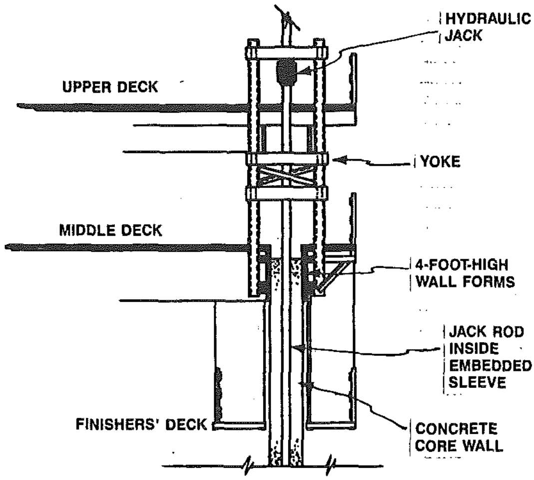

FIG. 8. Three Working Decks in Core Construction (Courtesy of Concrete Construction)

Datum/Moore Partnership, showed that slipforming would cost somewhat more than other construction methods but would shorten the project's total construction schedule by a minimum of three months.

Slipforming the core shortened the overall project schedule in several ways. In addition to the actual time saved by slipforming, elevator construction was able to be commenced early, eliminating this important item from the critical path on the construction schedule. Also, the slipformed core permitted the early start of structural steel, stairs, and other central-core items. Structural steel was already to level 12 when the IBM Tower slipform topped out.

Slipforming obviously has many advantages, but obtaining a finished structure that meets the necessary critical tolerances requires extensive experience in slipform construction and operation. While each feature of the core had its own set of tolerances, the core itself had to be within 2.5 in. (6.35 cm) of plumb for proper installation of the elevators. The contract called for completion of the entire IBM Tower slipform operation in 19 weeks, with five weeks for form and structural grid assembly, twelve weeks for slipping, and two weeks for dismantling the form.

The concrete contact areas of the form were constructed in Sundt's Phoenix, Arizona, yard and shipped to the job site. The steel grid was fabricated in Dallas, Texas. The jacking system was supplied by Heede-Uddemann, Inc., of Connecticut.

Sundt used a form comprising three working decks, as shown in Fig. 8. The upper deck, supported on a structural steel jacking grid, was used for landing, sorting, and storage of reinforcing steel, placement and lateral support of the vertical reinforcing steel, distribution of concrete, and control of the slipform jacking operation (Pruitt 1987).

Mounted in the jacking grid were 21 hydraulic jacks, each with a capacity of 22 tons (19.8 tonnes). The jacks were mounted on 3 in. (7.62 cm) diameter jack rods, which extended down into the concrete walls. The rods acted as support columns for the slipforming operation. During slipforming, the jacks pushed up on inverted "U-"shaped structural supports called "lifting yokes," which were connected to the steel grid on the top deck.

The jacks have a maximum jacking rate of 1 in. (2.54 cm) every 2 min, and use two sets of teeth to clamp on to the jack rods. This safety factor allows one set of teeth to be engaged at all times during slipforming.

Larger-than-usual yokes were used at nine locations on the grid of the IBM Tower slipform. Called "nuclear yokes" because they were developed for the construction of nuclear power plants, the yokes were spaced 20 ft (6.10 m) apart instead of the normal 6 ft (1.83 m). This wider spacing accommodated placement of the massive amount of reinforcing steel required for very large link beams, which were to be constructed above the entry to each elevator lobby. Steel for the link beams was placed at night, when the form was not in a jacking mode.

The middle level of the slipform, also called the working deck, was connected to the lifting yokes. It consisted of a plywood/structural steel floor system and the 4 ft (1.22 m) tall form, which was composed of a fiberglass-reinforced plastic surface on a structural plywood substrate. At the same elevation as the top of the form, the work deck supported the distribution and placement of the concrete and the installation of horizontal reinforcing steel, sleeves, block-outs, door openings, weld plates, and miscellaneous hardware.

Suspended below the middle deck was the finisher's deck, where workers finished the concrete, applied curing compound, installed elevator and spreader beams, installed structural tee clips on weld plates for structural beam anchorage, and removed block-outs.

Although many pitfalls are encountered on even the most simple slipform project, the principal ones are keeping the form level and the core plumb. In the early days of slipforming, the only tools available for checking alignment were a transit, an inter-connected water-level system, and specially-made, 45-lb (20.25 kg) plumb bobs suspended by piano wire. Sundt still uses the transits and water-level system to check the level of the form and guide it during the slipforming operation, but the plumb bobs have been replaced by lasers. The IBM project used two vertical lasers, manufactured by Spectro-Physics, mounted in opposite corners of the core at ground level. The vertical lasers, aimed upward at targets on the work deck, permitted virtually instantaneous detection of rotation and out-of-plumb movement, as shown in Fig. 9.

Precise elevation measurements are also required for the proper placement of core penetrations, embed plates, etc. Again, modern laser technology was used. A horizontal laser was mounted on one of the jack rods and used with an electronic distance meter to mark the base elevation for each day's concrete pour. Bands of different-colored surveyors' tape were used to establish the vertical location of embeds, block-outs, sleeves, etc., on the reinforcing steel. The horizontal laser was mounted to one of the jacking rods because only the rods and the vertical reinforcing steel do not move during the slipforming operation.

A double check on the established base elevation for the day's pour was made with two steel tapes mounted in opposite corners of the core at a set elevation. The tapes extended up to the top deck and reeled out as the form

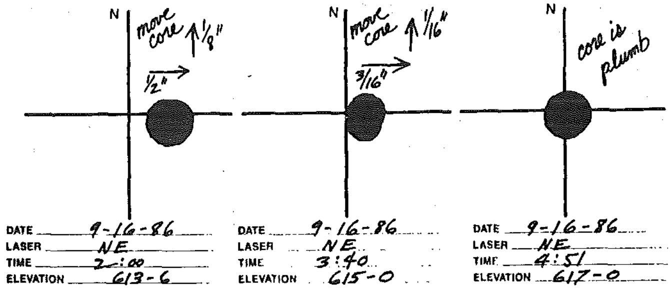

FIG. 9. Monitoring Slipform Movements by Lasers (Courtesy of Concrete Construction)

moved upward. The level of the form was also checked periodically by this method.

A total of 17,552 cu yd (13,340 m^3) of 6,000 psi (420 kg/cm^2) concrete was placed in the IBM Tower core, along with 2,570 tons (2,313 tonnes) of reinforcing steel. The bottom levels of the core had 350 lb of reinforcing steel per cu yd (207 kg/m^3) of concrete. This record ratio of steel to concrete challenged the crew frequently during concrete placement and required the constant and careful use of air-powered vibrators.

Coordination of tower crane usage, particularly with the general contractor's third shift, was a necessity. Several techniques were adopted for the IBM Tower project that improved crane use during critical periods. One was to switch from prefabricated door block-outs to a system of slider panels and a header to form the block-out. This saved not only crane time, but a significant amount of labor cost as well.

The second method of decreasing crane time involved pulling the jack rods with a reverse hydraulic pump rather than with the tower crane. The rods can be left in place, but at a cost of \$2/lineal ft (\$6.56/lineal m), Sundt prefers to reuse them whenever possible.

Efficient use of the tower crane for jumping the hoist was made by scheduling this activity for the night shift, between the time that the reinforcing steel was being loaded and the time of trash removal. Also, the tower crane tie-ins were located so that the jumping of the crane took place on weekends.

A unique system for erecting the elevator lobby structural steel and exterior structural steel was employed on the project. A trolley system was mounted to the structural steel support on form's middle deck, which allowed the steel erector to install beams and decking within three levels of the finisher's deck.

Design of the IBM Tower required a large amount of wall thickness variation—from 1 ft 0 in. to 2 ft 10 in. (30.48 to 86.36 cm). The thicker walls posed a stripping problem, which was overcome by using either tapered fiberglass block-outs (for frequently repeated penetrations), or tapered wood block-outs wrapped in plastic and coated with grease (for unique penetrations).

The difference in wall thickness also could have interfered with the concrete placing and jacking operations. The concrete in narrow walls sets up much faster than that in thick walls, because of the heat generated by

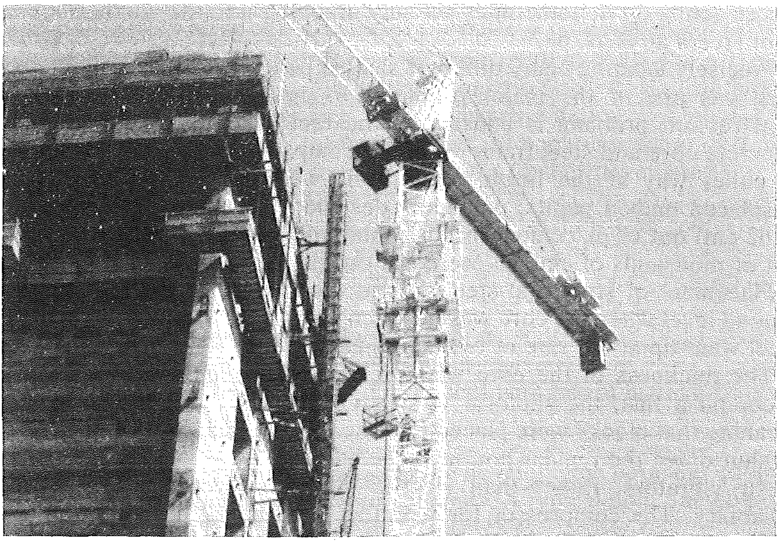

FIG. 10. Three Stage Laser Guide Slipforming

hydration. This presents the possibility of narrow walls setting up prior to being able to raise the form—a very serious problem if it develops. To prevent that from happening, the thicker walls were poured before the narrow walls during the slipforming operation.

The concrete pour usually started at top of the lowest door block-out on the floor and proceeded to the top of the lowest door block-out on the next floor. This made it possible to install the complicated reinforcing steel and long shear plates in the link beams during the night shift.

Fortunately, the IBM Tower in Atlanta did not present any of the cold weather problems that Sundt has encountered on other projects. During the winter, it is often necessary to insulate and enclose the form and a section of the core below it to keep the concrete at a proper temperature for curing. On some occasions, thermocouples were embedded in the concrete of winter-constructed slipforms to monitor this critical factor continuously for several days after the concrete has been placed.

Operation of Slipforms

As the form climbs, it builds its own base, as shown in Fig. 10. During construction, wind tends to bend the core. The sun makes it hot on one side while the shaded side remains cooler, which tends to warp it. Sometimes the uneven rate of hardening of the concrete itself adds a torque force. Varying the forces exerted by each of the 21 jacks, and changing the amount of steel rebar on the top deck makes it possible to steer the core straight. The top of the core is within 1.5 in. (3.81 cm) of plumb over its height of 725 ft (221 m). The allowable tolerance was 2.5 in. (6.35 cm).

In fact, the slipform was rarely in truly balanced position. Operators continually alter the elevation of the form to compensate for the different

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forces acting on it, sometimes actually crabbing into the wind, much as a pilot steers an airplane.

Precisely locating many different-shaped penetrations for building services was one of the major problems in designing the core. A major construction problem is caused by the fact that the tolerances of the concrete core and steel frame were not compatible. One in. (2.54 cm) slip in either way at the beam connections were allowed. To reduce the misplaced embed plants, engineers designed the embed plates for 3 in. (7.62 cm) out of placement in horizontal and vertical directions. Only 10 out of thousands of embeds were left out or had to be redone.

Placement of structural steel around the outside of the core began at ground level when the core was between the 10th and 15th floor level. The steel went up at the rate of two floors each week.

The thickness of the core walls decreased at the 34th-floor level. To accomplish this, the slipform was "stepped back" while "on the fly," meaning that blocks were placed into the form at this level without having to shut down the regular pouring schedule.

Air vibrators, rather than electric vibrators, were used for greater reliability. The compressor for vibrators was mounted on the top level. Vibrators were lowered into freshly poured concrete to remove possible air pockets.

Sequence

The form was manned on a basis of three shifts daily. There was a total of 110–130 men working on the form each day. The first shift placed horizontal reinforcing steel and placed concrete in the form using conventional concrete buggies loaded from larger hoppers, which were mounted on the top level. These hoppers were fed by a ground-mounted tower crane that climbed along with the slip form and fed concrete from trucks on the ground. The second shift cleaned the form, stocked it with reinforcing steel, and placed vertical reinforcing steel. This shift also put in place structural steel elements to be embedded in the concrete core wall and other block-outs for doors and other passages. On the third shift, ironworkers placed structural steel "elevator spreader beams." These beams, placed in the open spaces within the finished core, formed the bracing for the elevator shafts. Each shift included different skilled craftsmen who worked in close coordination within the relatively small work space. One man worked full-time on operating the jacks, and another man's full-time job on each shift was safety and fire prevention.

Value Engineering

This part of the paper describes the selection process for the structural framing system. The final selection was made by the owner at the end of a comprehensive, three-phased value engineering study. In Phase I, 11 floor-framing systems and eight wind-framing systems (which in combinations gave 42 possible schemes for the structure) were developed by Datum-Moore. Schematic information consisting of member sizes for each scheme was provided. These schemes were then reviewed by the design team for functional requirements, and by the contractor from a construction viewpoint. In this review, 19 schemes were determined to be unsuitable and were eliminated.

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In Phase II, pricing information in the form of pounds per square foot of rebar or structural steel was developed for the remaining 23 schemes. The contractor transformed this information into relative costs for a typical floor of each of the schemes. The time of construction of a typical floor, a factor directly related to the cost of interim financing, was estimated for each scheme, as shown in Table 1. Based on economic feasibility, the owner selected the following four schemes for further development:

1. Scheme I: Composite steel floor beams at 10.0 ft o.c. (on center) (3.05 m), composite exterior columns, and slip-formed core.
2. Scheme II: Post-tension floor beams at 30.0 ft o.c. (9.15 m) with joists between beams, concrete exterior columns, and concrete core.
3. Scheme III: Post-tension floor beams at 30.0 ft o.c. (9.15 m) with joists between beams, and exterior moment resisting tube.
4. Scheme IV: Same as Scheme III, except with use of haunch girder in lieu of post-tension beams.

The third and final phase consisted of the development of beam, column, and shear wall schedules for the four schemes. A typical floor and columns

TABLE 1. Relative Costs of Typical Floor of Phase II Framing Schemes

Scheme plan reference number (1)	Relative structure cost per floor (2)	Total relative cost per floor (3)	Estimated construction time per floor (in days) (4)
SPR-1	$377,701	$412,344	3–4
SPR-1 ALT.[1]	389,837	400,285	4
SPR-2	385,151	425,180	4
SPR-2 ALT.	408,428	423,792	4
SPR-3	376,404	408,407	5
SPR-3 ALT.	387,371	395,809	5
SPR-4	314,966	327,650	6
SPR-5[1]	308,300	309,886	6
SPR-5 ALT.	312,610	314,196	6–6.5
SPR-6	280,966	293,650	7–8
SPR-7[1]	280,248	281,894	7–8
SPR-7 ALT.[1]	284,111	285,697	8
SPR-8	511,680	546,323	6
SPR-8 ALT.	449,840	460,288	6
SPR-9	501,809	541,838	5
SPR-9 ALT.	441,341	456,705	5
SPR-10	523,143	555,146	6.5
SPR-10 ALT.	448,403	456,841	6.5
SPR-11	506,484	541,127	4–5
SPR-11	484,943	495,391	4–5
SPR-12	514,304	546,307	5–5.5
SPR-12 ALT.	474,294	482,732	5–5.5
SPR-13	367,045	371,587	6

[1]Selected for further development in Phase III.

TABLE 2. Cost Comparisons of Phase III Framing Schemes

Scheme (Plan ref.) (1)	Structure cost per sq ft (2)	Foundation and site excavation cost per sq ft (3)	Construction time (in weeks) (4)
Scheme I[1] (SPR-1 ALT.)	$16.06	$1.56	104
Scheme II (SPR-5)	15.34	1.63	128
Scheme III (SPR-7)	15.58	1.46	114

[1]Selected as the final scheme.

and wind-resisting elements for the entire height were designed. Using this information, the unit (per sq ft) cost of structure and the total construction time for Schemes I, II, and III were developed by the contractor (see Table 2). No cost data for Scheme IV is available.

Scheme II was first to be eliminated, because of its excessive construction time. Schemes I and III were considered very close in overall economic feasibility. Scheme I had a premium of \$0.58/sq ft (16.06/sq ft + \$1.56/sq ft. − \$15.58/sq ft − \$1.46/sq ft = \$0.58/sq ft); (\$6.24/m^2), but saved 10 weeks in construction time in comparison with Scheme III. The owner selected Scheme I at an estimated structural cost of \$16.06/sq ft (\$172.87/m^2), and \$1.56/sq ft (\$16.79/m^2) cost of foundation with a 104-week construction time, because of the benefits of the shorter construction schedule. The slip-form core in Scheme I was further optimized by studying five possible core layouts for functional, structural, and economic factors (Cheema and Horn 1985).

CONCLUSION

The IBM Tower in Atlanta is a fascinating example of architectural, engineering, and construction innovation and practice. The owner has acted as the construction manager, coordinating the design and construction between the architectural and engineering teams and the general contractor. This team approach has resulted in a maximum amount of quality construction being accomplished in minimum time, and the project being completed within a tightly controlled schedule.

Because of the complexity of its design, it required a unique form of construction—slipforming. The use of this construction process enabled the contractor to keep construction time on the building to just 25 months. Using a slipformed core kept lease space totally column-free.

The engineer designed the structure so that exterior composite columns pass wind loads through the building's composite floors to the core. Tension forces resulting from wind loads are resisted by core anchors embedded 20–30 ft (6.10–9.14 m) into rock. The core foundation consists of drilled piers under 10 ft (3.05 m) wide, 8 ft (2.44 m) deep cap beam that links all the piers into a single wind-resisting system. Value engineering

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study considered 42 different floor-framing and wind-framing systems. Slipformed concrete core with structured steel floor framing and composite exterior columns was selected. The analysis showed that slipforming would cost somewhat more than other construction methods, but would shorten the project's total construction schedule by a minimum of three months.

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Appendix I. General Statistics for IBM Atlantic Center Tower

Tons of Reinforcing Steel	
Rebar in Foundation:	737 tons (663.3 tonnes)
Rebar in Core:	2,435 tons (2191.5 tonnes)
Rebar Balance:	1,316 tons (1184.4 tonnes), projected
Total:	4,488 tons (4039.2 tonnes), projected
Tons of Structural Steel	
Perimeter:	Approximately 5,046 tons (4541.4 tonnes); 45,174 pieces
Core:	Approximately 591 tons (531.9 tonnes); 23,530 pieces
Total:	5,637 tons (5,073.3 tonnes)
Cubic Yards of Concrete	
Foundation:	4,117 cy (3,129 m^3)
Core:	17,552 cy (13,340 m^3)
Balance:	30,850 cy (23,446 m^3);
Total:	52,519 cy (39,915 m^3); projected
Concrete Types	
Floors:	3,000 psi (210 kg/cm^2)
Piers, Grade Beam, Slab-On-Grade:	5,000 psi (350 kg/cm^2)
Columns:	7,000, 6,000, 5,000 psi (490, 420, 350 kg/cm^2) as noted
Core:	6,000 psi (420 kg/cm^2)
Basement Walls:	7,000 psi (490 kg/cm^2)
All Else:	4,000 psi (280 kg/cm^2)
Floor Deck	
Metal Deck:	18 ga. (68 lit.) with 3″ (7.62 cm) ribs
Concrete Thickness:	3.5 in. + 3 in. = 6.5 in. (16.51 cm)

Granite

Type:	Spanish Pink Imported from Spain
Number of Pieces of Precast:	2,076 through level 46
Number of Pieces of Precast:	852 above level 46
Number of Pieces of Handset:	8,852 (estimate)

Curtainwall System

Glass:	1 in. (2.54 cm) insulated PPG Solar Gray
Reflective Quality:	Translucent natural glass reflection
Metal System:	Inside glazed custom pressure wall system

Marble

Main Lobby:	
*Walls	Lido-Morocco Calacata-Italy
*Floors	Nero Portora-Italy Negro Marquina-Italy Acqua Bianca-Italy

Mechanical System

Type:	Forced air, water cooled, electric heat
Zones per Floor:	8 interior and 12 exterior
Tons of Cooling:	(3) 1,240 ton (1,116 tonnes) chillers, 3,720 tons (3348 tonnes) total.

Appendix II. References

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