DESIGN FOR ERECTION CONSIDERATIONS

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For the erection of the hypothetical 24-story apartment building several types of construction equipment are discussed. Based on the selection of a climbing crane as a suitable method for erecting components of this building, a detailed analysis is performed on the crane capacities required, crane support frames, and typical floor girders of the structure to support the crane assembly. Additionally, foundation modifications are analyzed and discussed for the initial position of the climbing crane resting on ground level. Further discussions include climbing sequences, lateral restraint, and bracing.

The location of the climbing crane is based on positioning that would involve the least amount of interference with construction trades.

The climbing crane should be set up as soon as possible during the construction period in order to attain maximum utilization and advantage in not only lifting and placing precast elements, but hoisting other construction equipment and supplies.

When mass produced precast prestressed concrete elements were first introduced for building construction, structures using these elements were generally of a low rise type. Erection of the precast elements was simply handled by the use of conventional mobile truck cranes operated on ground level.

However, it soon became apparent that precast prestressed and non-prestressed concrete structural elements would also have advantageous application in high rise buildings. Foremost in the minds of many designers and builders pioneering this concept at that time was the question of placing these relatively heavy members in high building structures.

At that time, long boom, high capacity mobile cranes operating from ground level were used in some instances, but in general, they were severely restricted by property line clearances and building layout conditions requiring excessively long reaches.

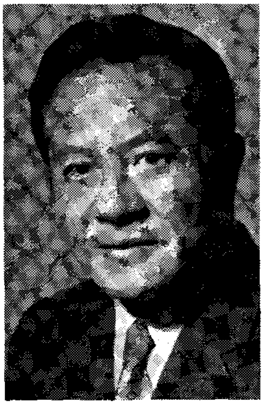
Tower cranes with horizontal jibs operating from a mobile platform also faced severe limitations due to member size and weight requirements as well as the geometric layout of the structure.

Climbing cranes were initially of low capacity and were deficient in both strength and reach to erect the usual structural precast elements for high rise building construction.

In the early pioneering years, some of our solutions for erecting heavy precast members in high rise structures included the use of winch-operated davits which were either attached to tubular tower hoist frames or columns of buildings. These davits worked in combination with manually-operated dollies which involved a considerable handling effort and time for placement.

In recent years, however, new high capacity climbing cranes were developed. These machines have contributed significantly toward lowering the cost of erecting precast prestressed concrete elements for high rise construction. Climbing cranes are now manufactured to capacities and heights that can handle almost any construction problem involving the use of precast concrete elements. With these machines, the number of building stories is no longer limited by erection considerations since the climbing crane moves upward as the building increases in height.

This paper presents the design steps and detailed computations for erection considerations of the example 24-story apartment building. All discussions will be based on the selection of the high capacity climbing crane as the instrument for structural erection. A discussion of erection sequence and bracing methods will also be included.



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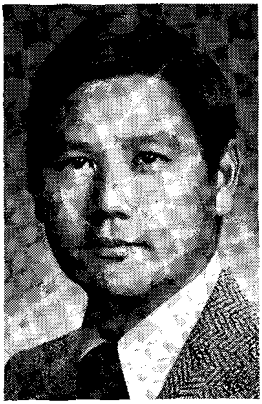

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LOCATING THE CRANE

The initial selection of the climbing crane position relative to the building geometry is extremely critical (see Fig. 1). Note from Fig. 1 that the position we have selected does not fall in the center of the building, but somewhat off to one side.

The reason for this selection is that we must avoid the elevator shaft location since elevators require a considerable amount of lead time for final installation. Positioning the crane in the elevator shaft will delay elevator installation as the crane will be used for a considerable length of time, even after the building is topped off, and therefore, its presence in the shaft would be obstructive. The climbing crane was

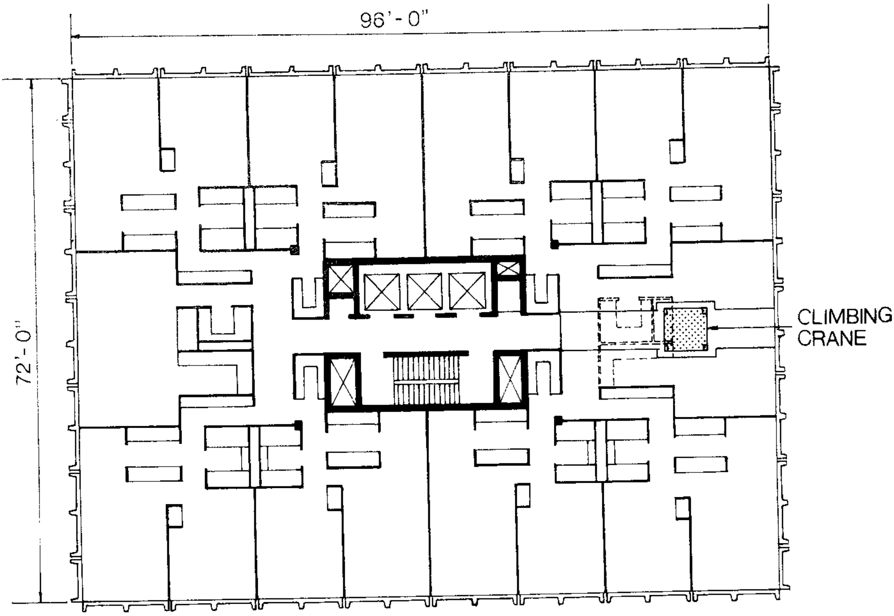

Fig. 1. Climbing crane location on architectural floor plan.

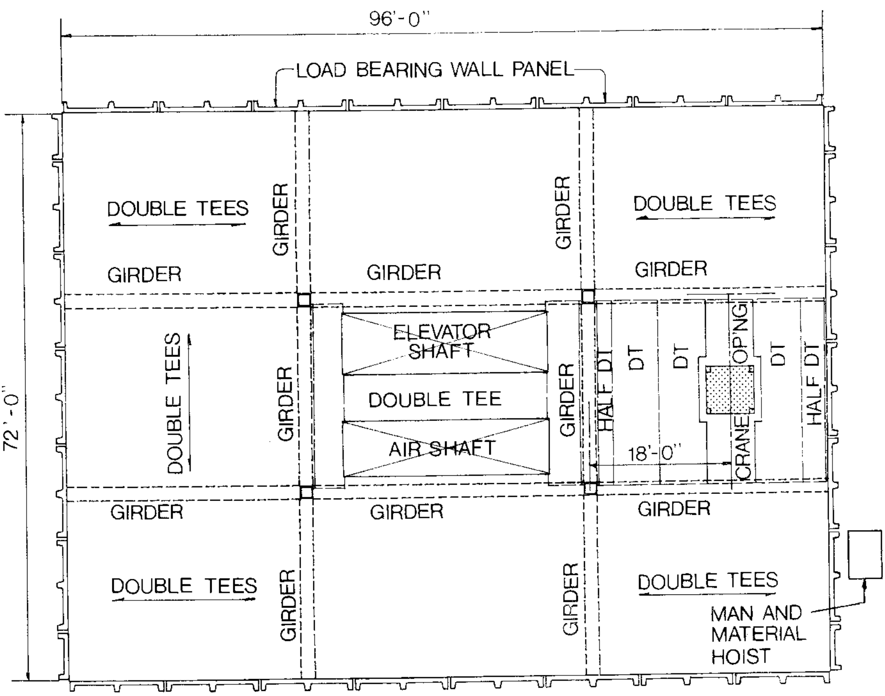

Fig. 2. Structural floor plan for even-numbered floors. (On odd-numbered floors the double tees were rotated 90 deg.)

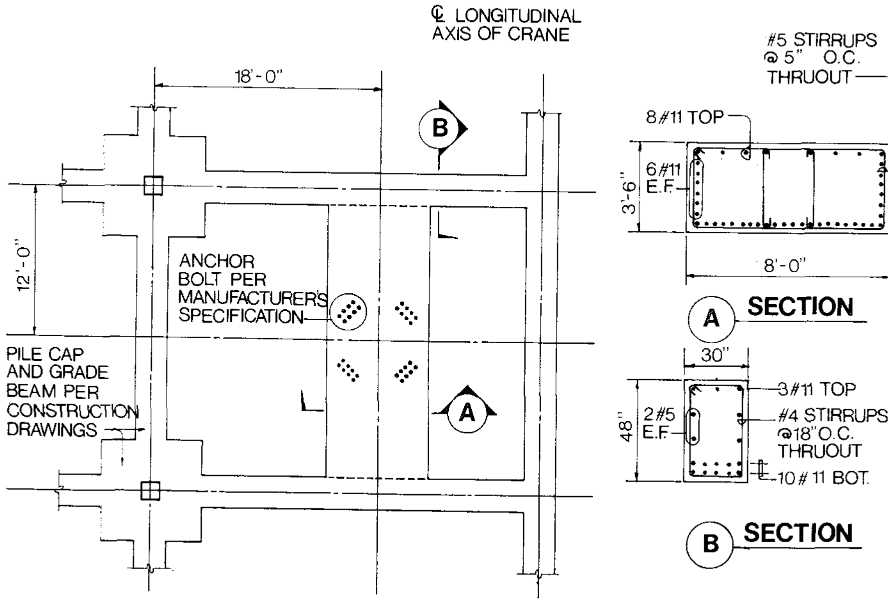

Fig. 3. Crane foundation plan for free-standing condition.

not located in the stair shaft as this area is important for workmen's daily access between floors of the building.

It should also be noted that the final position of the crane is located in such a manner as to avoid interior partitions of the apartment layout. In the location selected, most of the interior work of the building can be finished without interference as the mast of the crane climbs upwards. For the final location, consideration was given to the span requirements of the floor girder and double-tee layouts (see Fig. 2).

SIZING THE CRANE

The selection of the type of climbing crane to be used must be based on the anticipated reach and maximum loads imposed by the structural units to be erected. An analysis of the weight and location of various precast elements with respect to the crane mast location indicates, for example, that a Pecco crane, Model PC 1600, with a Type K jib, would be adequate for this project.

Of course, there are other types of climbing cranes that can also meet these requirements, but for the purposes of this paper, we will use the data from the Pecco 1600.

Data on crane capacity characteristics and calculations showing maximum reach and weight of units are reviewed in the Appendix.

The Pecco 1600 crane has a maximum capacity of 6.4 tons at a reach of 115 ft.

For the typical floor, the furthest wall panel unit is located 89 ft from the crane mast and weighs 7.15 tons.

The furthest floor girder unit is located 70 ft away from the crane mast and weighs 6.48 tons.

The furthest double tee floor unit weighs 3.24 tons and is located 84.5 ft from the crane mast.

Thus, all of these units can be adequately handled by the Pecco 1600 crane in the location shown in Fig. 1.

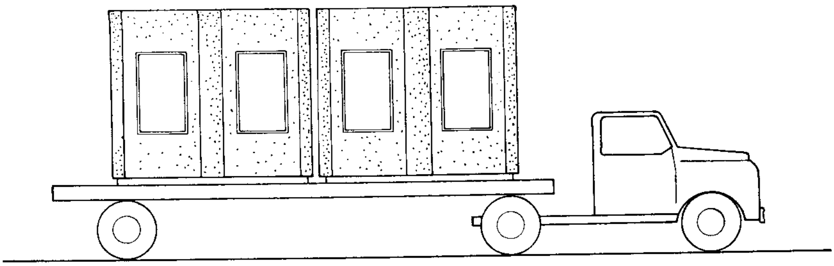

Fig. 4. Transporting bearing wall elements.

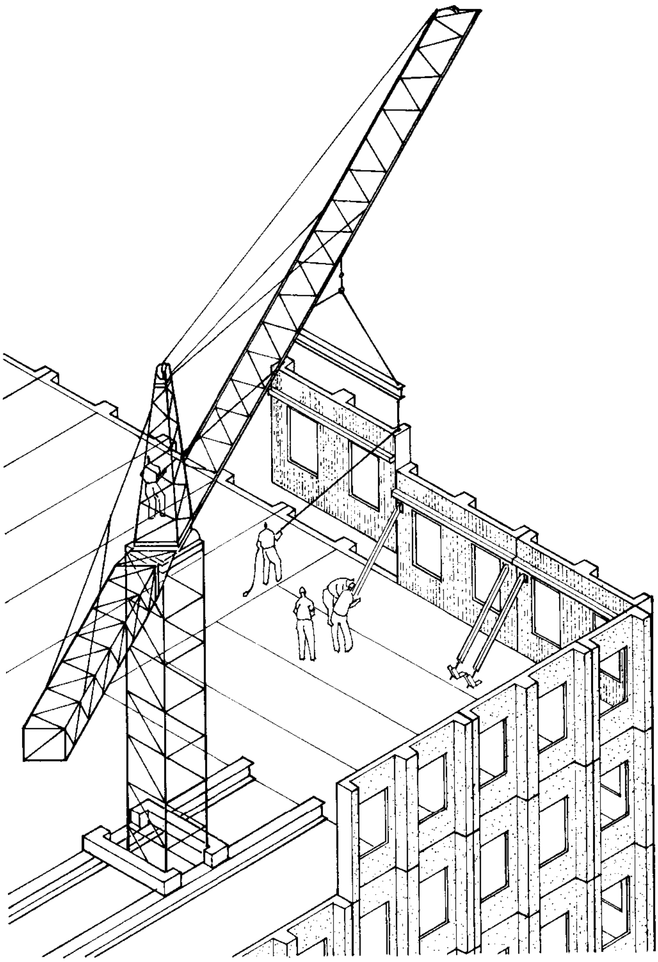

Fig. 5. Placing and positioning of precast bearing wall units.

ERECTION PROCEDURE

Computations for the crane foundation and support frame as well as the revised framings within the building are included in the Appendix.

The climbing crane is erected as soon as possible at ground level to start the construction. Fig. 3 shows a specially designed footing for the climbing crane which is integrated with the permanent building construction footings.

After the foundation pile caps and grade beams are concreted, the climbing crane will erect the precast wall panels and precast columns.

Following this, the precast girders and double tees of the first floor will be erected and the 2½-in. concrete topping will be cast.

Figs. 4 and 5 show a method of transporting, positioning, and bracing the precast wall units. These elements, which are placed by the climbing crane, are shimmed to the proper elevation and are braced and plumbed with an adjustable strut prior to releasing the crane line. The precast wall panel placement begins at one corner of

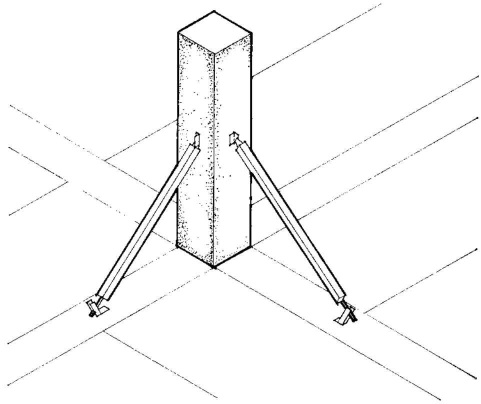

Fig. 6. Typical precast concrete column bracing scheme.

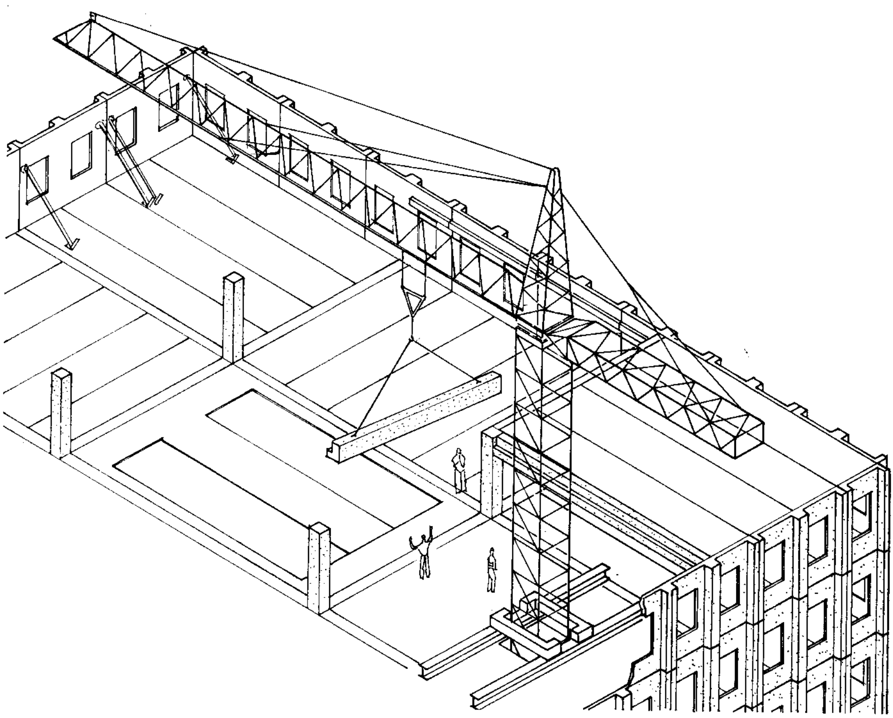

Fig. 7. Placing precast prestressed girder.

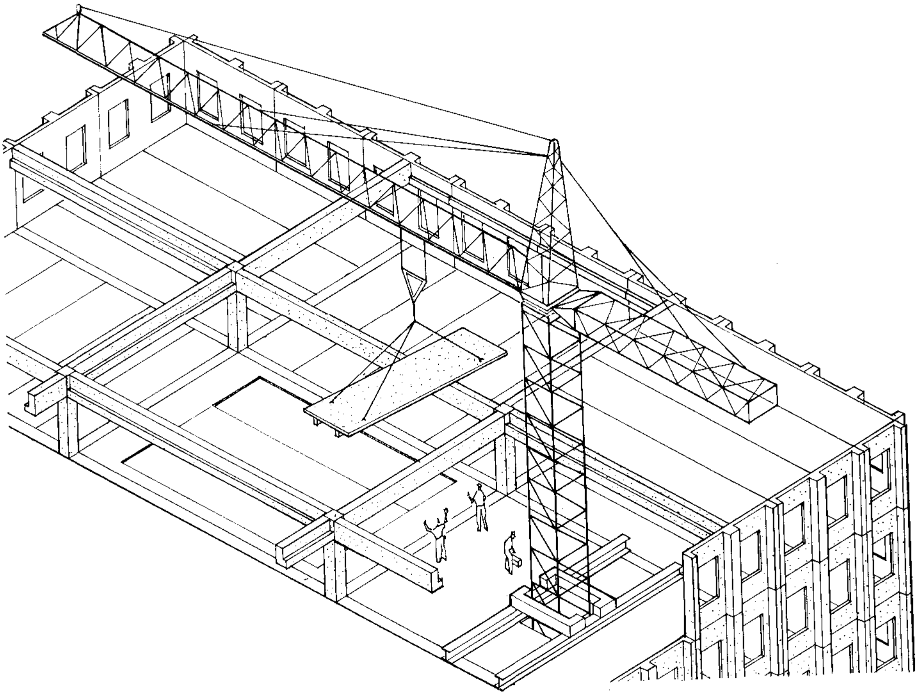

Fig. 8. Placing precast prestressed double tee.

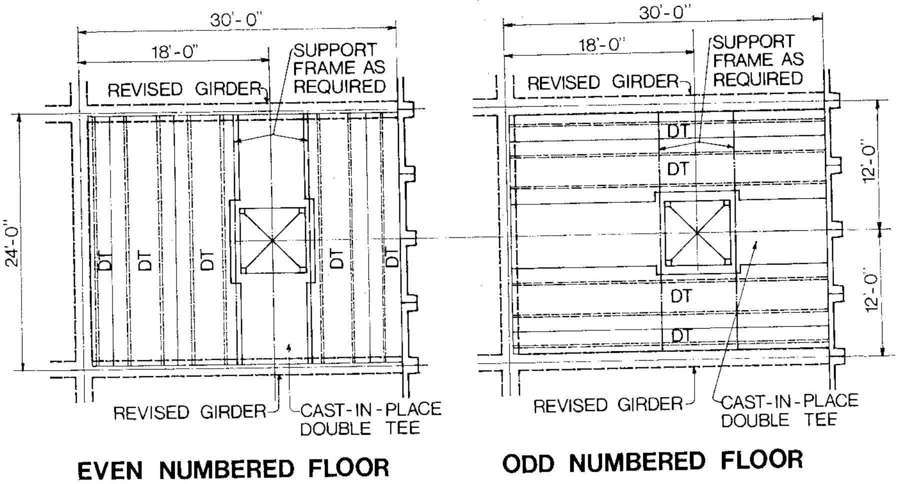

Fig. 9. Revised typical floor layout to accommodate climbing crane.

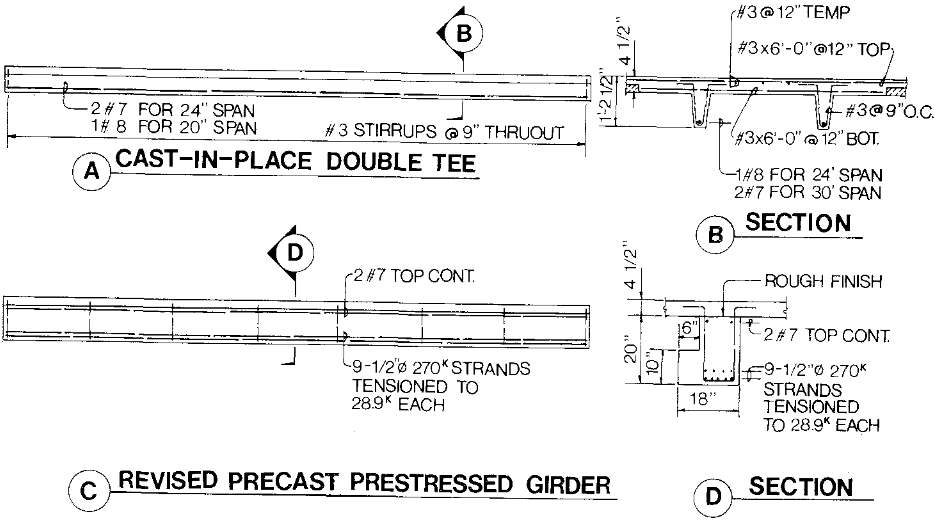

Fig. 10. Revised precast prestressed girder and cast-in-place double tee.

the building and proceeds in sequence around the perimeter of the building.

After the wall panels are erected, the precast column erection will follow. The base of the column will be shimmed to provide a proper top elevation and will have two adjustable struts at 90 deg to keep the column plumb and rigid in two directions (see Fig. 6).

After completing the connections of the precast wall panels and columns in accordance with the contract details, the precast girders are placed (see Fig. 7). When this operation is finished, the precast prestressed double tees can be set in place (see Fig. 8).

It should be noted that the precast prestressed double tee in the vicinity of the crane location has been omitted to accommodate the crane mast. This area will have a reinforced cast-in-place double tee section and will be concreted after the crane mast passes through. For details of this slab closure see Figs. 9 and 10.

In addition to placing precast and prestressed concrete units, the cranes assist in lifting and positioning formwork, hardware, reinforcing steel, concrete, and other supplies.

CLIMBING SEQUENCE

Fig. 11 shows a partial climbing sequence for the crane while Fig. 12 illustrates the climbing mechanism located within the crane mast used to raise or lower the crane. The climbing crane selected has about a 100-ft clear working height under the hook. This means that the crane resting on the ground level can be used to erect the first, second, third, fourth, and fifth floors.

From the instruction manual prepared by American Pecco Corp., a minimum moment resistant arm of 21 ft 4 in. in height is required for stability of the crane mast. The floor-to-floor height in this 24-story building is 10 ft ½ in. Therefore, at least three floor levels between support frames are required to provide sufficient lateral stability to the crane.

This particular climbing crane must be worked with three sets of support

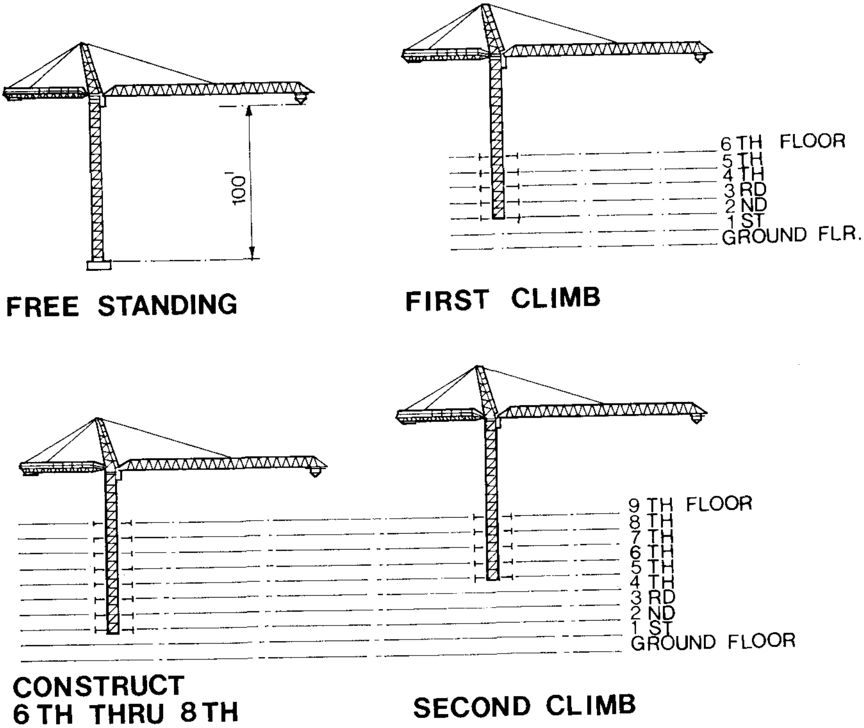

Fig. 11. Partial climbing sequence.

frames (see Fig. 13 for details) for a proper climbing operation. Two sets of support frames are used to support the climbing crane during operation and the third set is positioned at the required upper floor to provide lateral support after the crane mast passes through the lowest support frame.

For this project a single level of precast floor girders is not adequate to support the climbing crane loads. Therefore, the precast girders under the support frame of the climbing crane are strengthened not only by additional flexure and shear reinforcement but also by the addition of wood shoring to distribute the vertical crane load to five levels of precast girders (see Fig. 14).

Calculations for additional reinforcement and load distribution requirements are given in the Appendix. For the lower floor construction, there should be less than five supporting floors during the lifting operation. Furthermore, vertical shoring must be carried all the way to the ground level.

A study was made to find the optimum climbing sequence for the climbing crane. The results indicated that the bottom of the crane mast should be lifted to the second floor after the third, fourth, and fifth floors have been constructed. The vertical load of the crane is supported on the second floor girder system while the horizontal loads are resisted by the crane mast on the fifth floor level and second floor level.

It should be noted that these crane support frames (see Fig. 15) must be assembled in such a way that they can be disassembled and passed through the exterior wall window openings for relocation and placement by the climbing crane.

From this first elevated position of

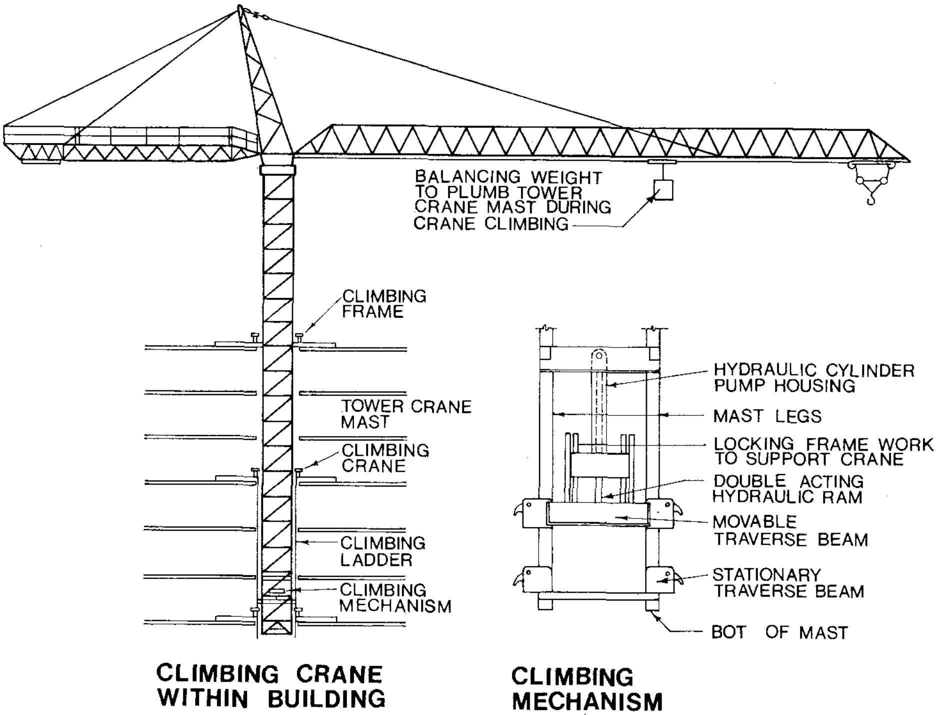

Fig. 12. Climbing crane within building (left) and climbing mechanism (right).

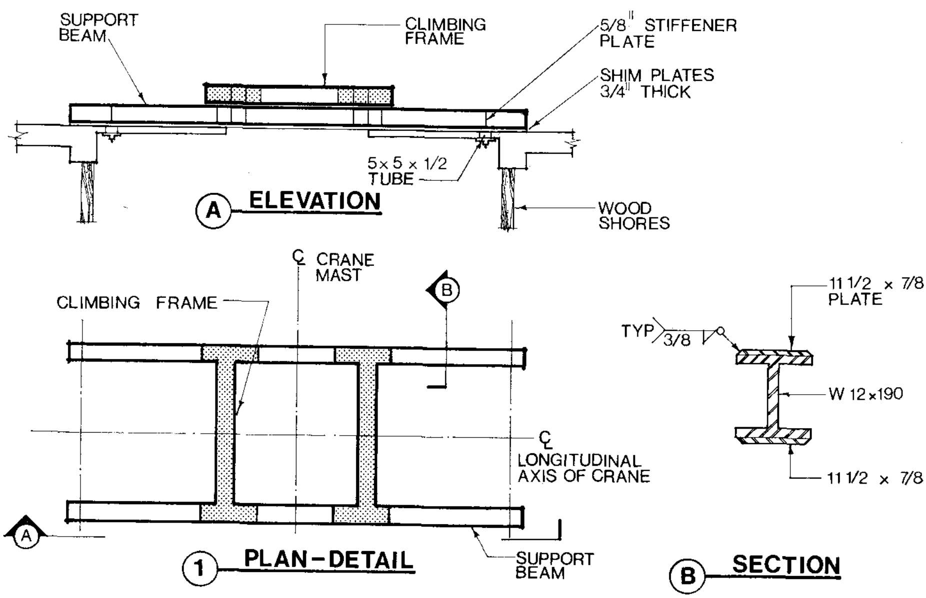

Fig. 13. Support frames for climbing crane within building.

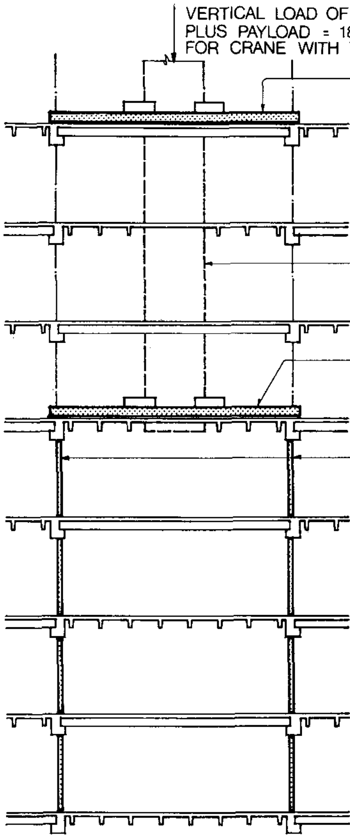

Fig. 14. Typical supporting system for climbing crane within building.

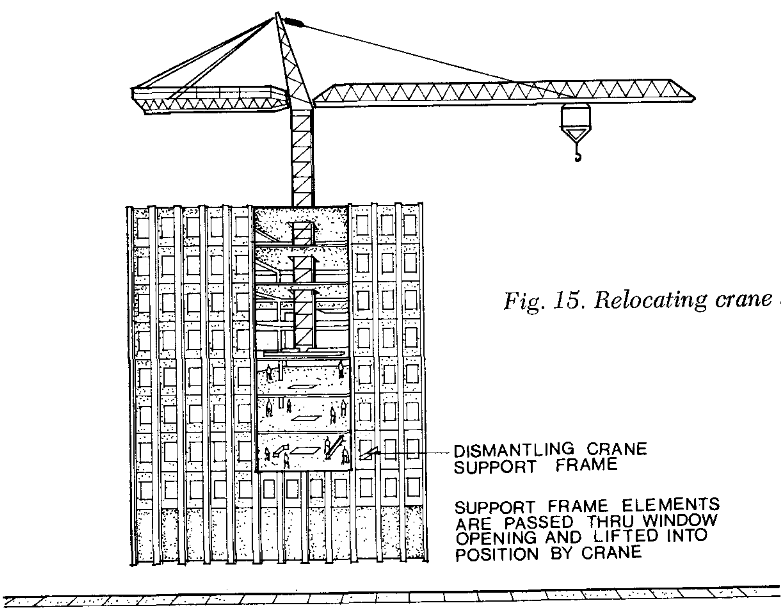

Fig. 15. Relocating crane support frame.

the crane, Floors 6, 7, and 8 can be constructed. Meanwhile, the floor slab opening on the first floor can be closed by cast-in-place concrete double-tee forms matching the existing double-tee elements.

The next vertical lift will bring the bottom of the climbing crane mast to the fifth floor. The lateral resisting height will be the fifth and eighth floors for the crane mast stability. From this position, Floors 9, 10, and 11 can be built. Meanwhile, floor slab openings can be closed with cast-in-place concrete on the second, third, and fourth floors.

The next lift will take the bottom of the crane mast to Floor 8, and the lateral resisting height will be between Floors 8 and 11. From this position, Floors 12, 13, and 14 can be constructed. During this time, floor slab openings can be closed on the fifth, sixth, and seventh floors.

This sequence continues until the crane mast is brought up to Floor 17 at which time the floor slab openings are closed on Floors 14 and 15. Slab openings in Floors 16 and above will not be closed until the crane is relowered for dismantling after topping off the structure.

From this position, Floors 21, 22, and 23 can be constructed. The next lift will bring the bottom of the crane mast from Floor 17 to Floor 20. The lateral resisting height of the crane mast will then be between Floors 20 and 23. From this position the crane can be used to construct the roof and penthouse machine room structure.

After completion of the superstructure, the bottom of the crane mast is lowered to the 16th floor so that the entire climbing crane assembly can be dismantled in sections and lowered down the side of the building.

The dismantling and lowering operation can be handled by a 140-ton crane with a long boom operating from the street level, or by the use of a stiff leg derrick located on the roof. The stiff leg derrick is preferred because it can then be used to lift forms and concrete for the cast-in-place closures from the 16th floor to the roof.

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Detailed numerical calculations supplementing the preceding erection design considerations will be published in the next issue of the PCI JOURNAL.
Typical computations will be given for selecting the size of the climbing crane and for designing the foundation of the free-standing crane.
Sections will include the design of the crane pad, the crane pad support beam, and the crane support frame.
The final section will give a suggested procedure for redesigning the structural floor framing and for analyzing the bearing walls.