

Composite Precast Concrete Connections

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of the Prestressed Concrete Institute

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In the past several years, I have found in Hawaii, that the maintaining of dimensional accuracy in the production of structural concrete units is somewhat of a problem. Since concrete is a heterogenous material and its physical properties can be affected by a great number of variables such as type of aggregate, cement content, curing methods and many other factors, it is not unusual that precast, prestressed members may suffer dimensional discrepancies in length, camber or lateral twist. In addition to this problem, the human factor in the production of these units plays an extremely important role. A misplacement of metal inserts for connections or a mismeasurement of cast lengths can seriously compound the problem, especially where the connection detail depends critically on accuracy. Costly errors both in field and factory due to dimensional inconsistencies can be a discouraging aspect of the rapidly growing prestressed, precast concrete industry. This paper is devoted to the discussion of a type of connection whereby poured-in-place composite concrete is used to fill the gap between and tie-together precast members.

First of all, poured-in-place concrete can easily absorb dimensional inconsistencies of the precast members and, therefore, can allow a greater manufacturing tolerance without sacrificing the actual struc-

tural strength of the connection. Continuity and interaction between framing members can easily be developed and, furthermore, the connecting steel tendons are completely enveloped by the poured-in-place concrete. Such joints then are not only more durable and fire resistant but can actually be made aesthetically pleasing since there are no exposed metal inserts, bolts or plates.

In figure 1, the most commonly used joint is described for the composite deck framing types shown in figure 2. The joists are connected to a poured-in-place beam by simply having the ends extended into the poured concrete which is usually placed in the same operation as the deck slab. The carrying beam can also be constructed in a composite manner such as shown in the interior beam connection where a precast, prestressed soffit was used. The ends of the precast, prestressed joist are completely enveloped with poured concrete so that uniform bearing about the entire end of the joist can be developed. The tapered ends of the joist serve to increase its bearing on the poured concrete portion. The extended strands are used to develop additional shear resistance and to help tie together the joint. For example, should the joist in manufacture inadvertently be made an inch or two longer or shorter, the structural integrity of this joint is not disturbed at all. There are no complicated or expensive devices such as inserts to be fitted,

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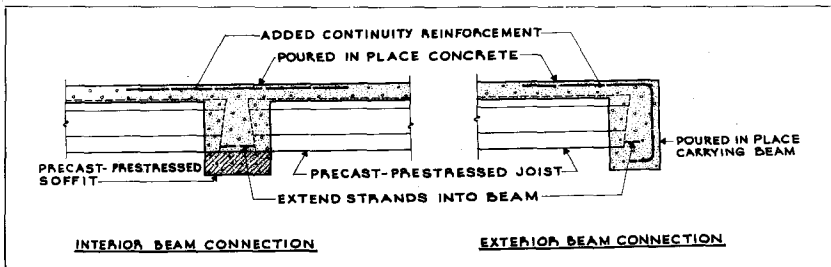


Fig. 1—Connection of precast, prestressed joists to composite beams.

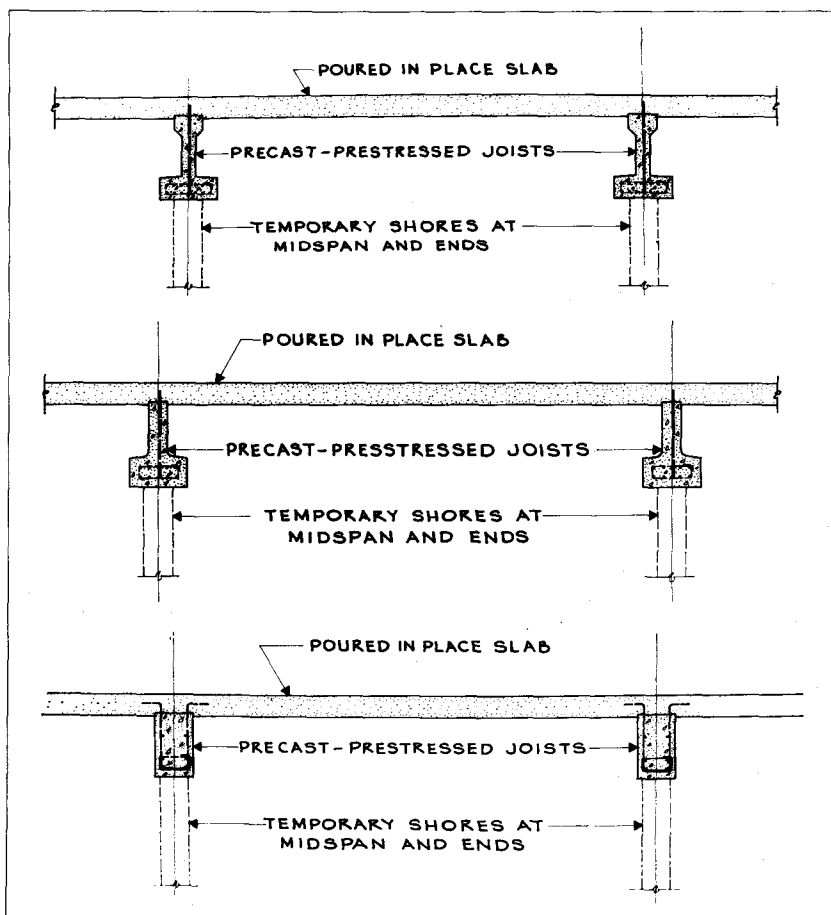


Fig. 2—Composite deck framing systems.

and, therefore, this joint allows a substantial amount of tolerance in the manufacture of these precast units. In the hundreds of structures that have used this simple connection so far, there has not been one case of concrete spalling or any other indication of distress.

Added continuity reinforcement can be conveniently located in the composite concrete deck slab. The amount of continuity steel added over an interior beam connection such as in figure 1, is usually computed on the basis of continuous beam action. In general, all elements of design should conform with ACI 318 Standards. However, in some cases where the precompression in the bottom fibers of the precast, prestressed joist is extremely high to start with, the negative moment steel may increase the stress in this area to an excessive degree. In this case it may be advisable to reduce the amount of continuity bars in order to maintain the bottom fiber stresses within a reasonable range. In our designs, these working stresses have been allowed to approach as high as $0.60 f'_c$, and this was accomplished by the addition of closed stirrups in the bottom flange of the precast, prestressed joist. The action of these stirrups is to resist the bursting action which is likely to occur under high compressive stresses. Furthermore, for purposes of economy, since strands usually develop a higher tensile force for less cost than ordinary reinforcing bars, it is sometimes more desirable to increase the number of prestressing steel strands in the precast joist so that it can take a greater amount of positive moment. This will, in effect, reduce the amount of negative moment reinforcing steel required. In any case, the added con-

tinuity reinforcement should be sufficient to develop at least the live load moments and must be embedded long enough to develop its full yield stress.

Where headroom is critical or other architectural features govern, it is sometimes desirable to make the precast joist soffit flush with the connecting poured beam soffit, such as shown in figure 3. With this type of joint, reinforcing steel "U" straps embedded in the poured concrete could be used to positively support the precast joist ends.

Where spans are long or loads are heavy, not only end shears are important but end rotations of the precast joist due to mid-span deflection could induce a torsional problem in the poured-in-place carrying beam. This problem can be alleviated by pouring the composite deck slab in sections and decentering the shores to release most of the end rotations before sealing the ends with concrete as shown in figure 4. This practice was adopted for a 19-story building now under construction in Honolulu, and figure 5 shows a cross section of this structure.

Column Connections

Precast, prestressed concrete joists or beams can be connected directly to precast concrete columns simply by the method shown in figure 12. The column unit is first precast in a horizontal position with its main reinforcement continuous for several floors. At each floor line a section of the column concrete is boxed out to later allow the deck beam continuity reinforcing to pass through the column, and at the same time provide an area for a poured-in-place concrete corbel which joins the intersecting precast beams to the column. The beams should have strands extended into the corbel area to

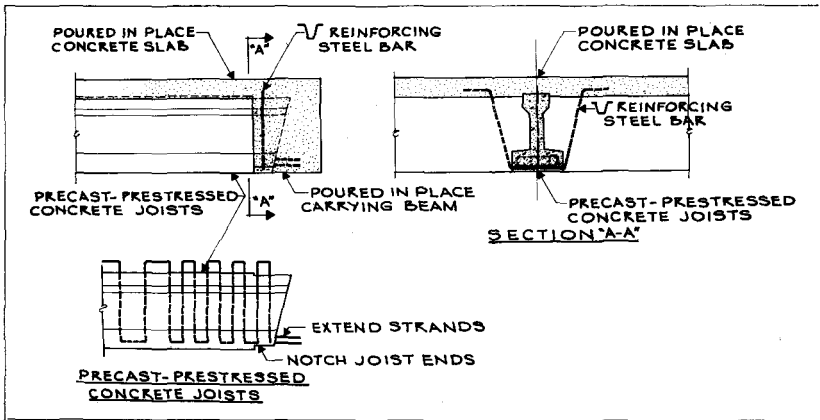


Fig. 3—Joist to beam connection with flush soffit.

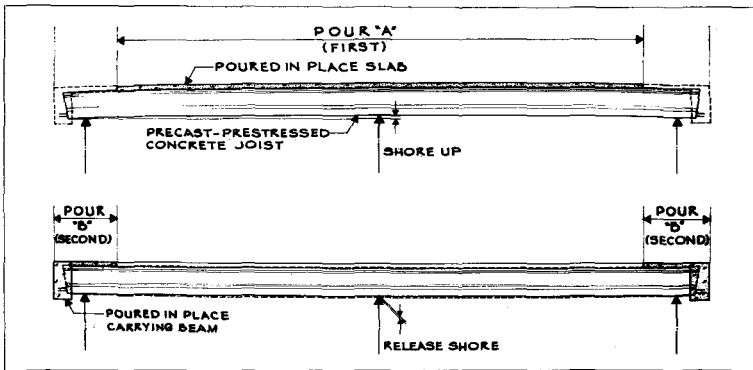


Fig. 4—Procedure for reducing torsional stresses in beams due to end rotations at joist connections.

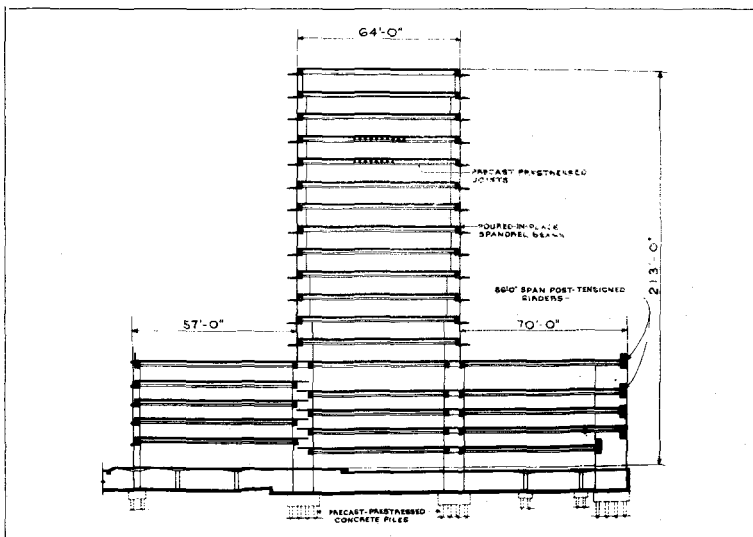


Fig. 5—Structural cross section of First National Bank Building, Honolulu, Hawaii.

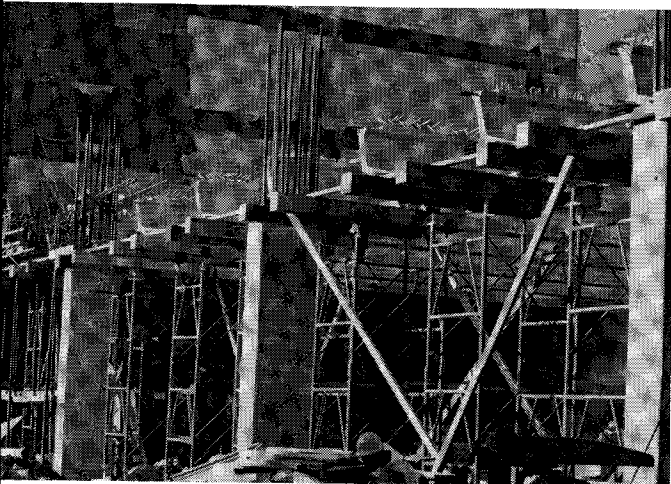


Fig. 6—Prestressed, precast concrete joists resting on temporary shores, ready for poured-in-place connection to the spandrel beam.

Fig. 7—Erection of prestressed joists.

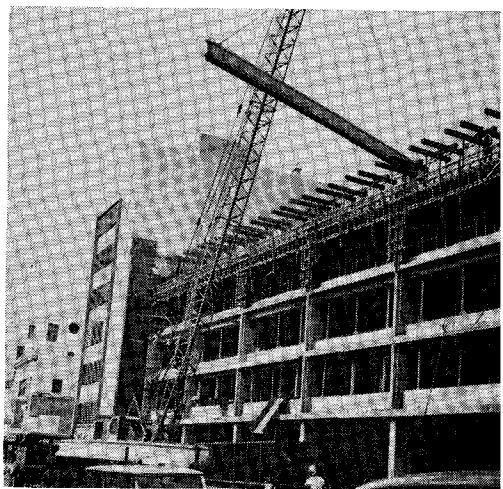
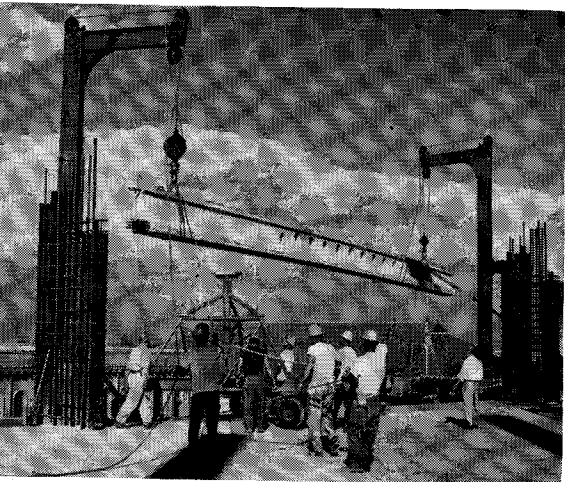


Fig. 8—Because of limitations on available equipment the upper floor joists were hoisted by a movable davit.

Fig. 9—Joists were handled on the upper floors and lowered into place by employing mobile tripods.

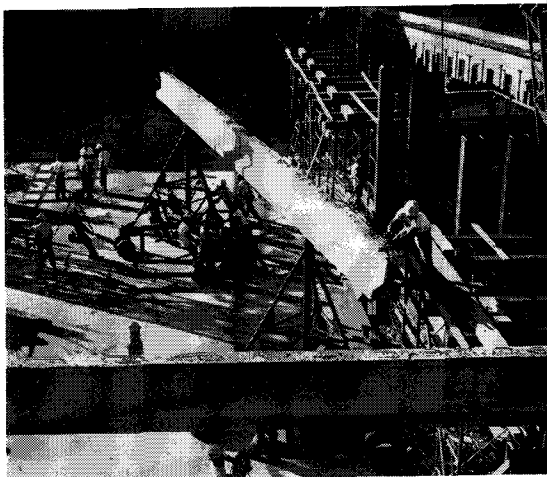
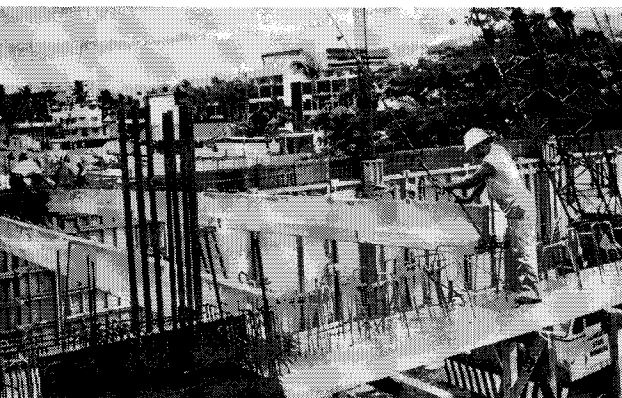
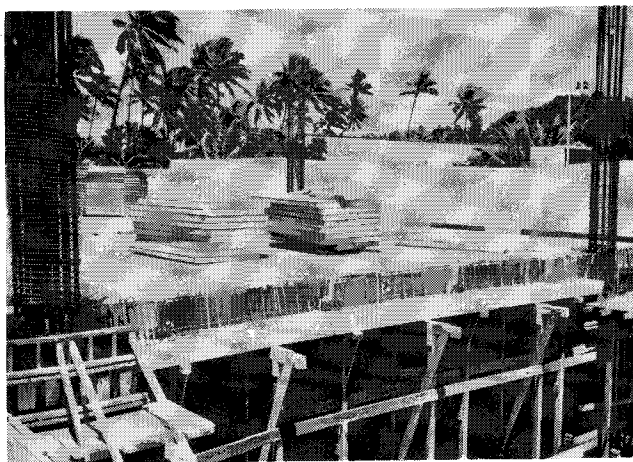


Fig. 10—Connection between prestressed joists and composite prestressed concrete beam. The joist simply rests on a precast, prestressed soffit whose upper portion is poured-in-place together with the deck slab.

Fig. 11—Forming of composite framing system.



develop both shear and moment. It is important that a cage of small diameter reinforcing steel ties be used to "contain" the poured-in-place concrete corbel and prevent any local spalling, especially at the point where the precast units butt up against the poured-in-place concrete. With this type of joint, the manufactured precast beam can have dimensional errors up to several inches in length without affecting the structural integrity or the cost of completing this joint. If the dimensional discrepancies are large, the formwork can simply be extended out to meet the precast beams and the poured-in-place concrete corbel will absorb all dimensional inconsistencies and develop full bearing and continuity at the joint.

An underground parking garage planned for construction in the near future will feature two basic precast components as shown in figure 15. All column units are identical, and the precast beam units for the second floor and roof have the same cross section. The column units are designed to develop continuity with the precast prestressed deck beams.

Moments are transferred through the poured-in-place composite joint by means of extended reinforcing bars embedded in the poured-in-place concrete slab as shown in figure 16. Both the roof precast beams and the second floor precast beams can be made of the same cross sectional design by tilting the columns so that the heavier soil loads on the roof will be carried on shorter span beams while the lighter second floor automobile loads will be carried on longer span beams. By manufacturing all prestressed beams to only one type of strand pattern and all columns to one set of dimensions, considerable economy is achieved.

The column bases are fitted into precast concrete footing sockets which are later filled with expansion grout. These over-sized footing sockets allow for complete flexibility in vertical and horizontal adjustment in setting the columns while the poured-in-place corbel connections also allow the same adjustments in the superstructure. Structural integrity is maintained throughout and full continuity between precast members is easily developed.

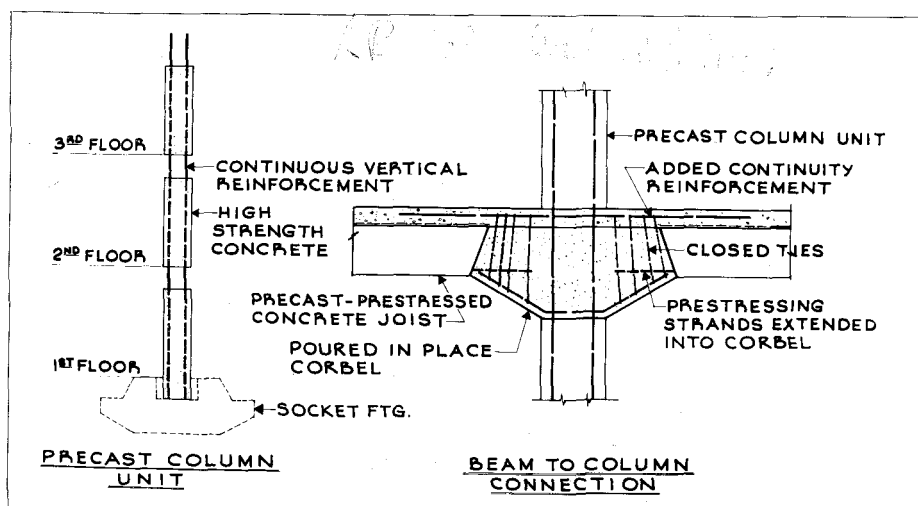


Fig. 12—Connection between precast column units and precast joist units.

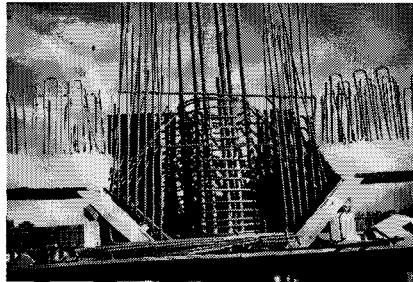


Fig. 13—Connection of the prestressed beam soffits to the column corbel. Note the tapered end of the soffit and its extended strands into the corbel.

Fig. 14—Close-up photograph of the completed composite connection between joists, beams, and a corbel.

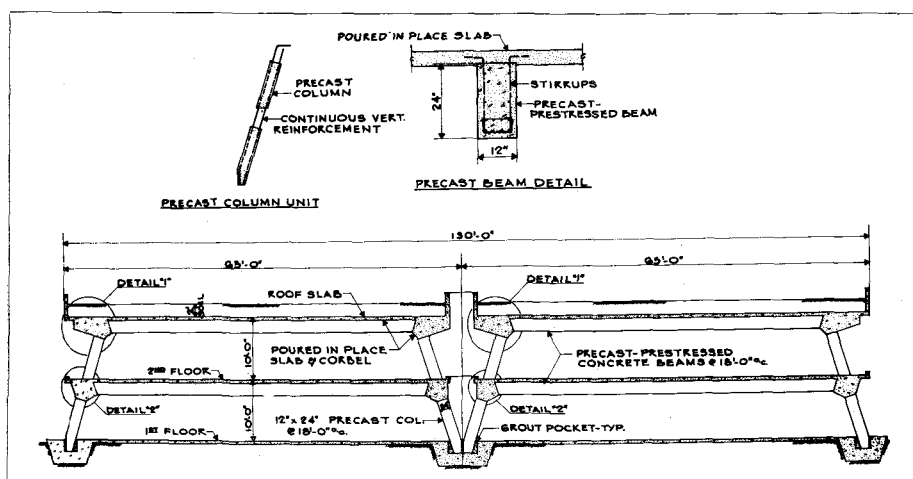


Fig. 15—Proposed framing for an underground parking garage using two basic precast units—columns and beams.

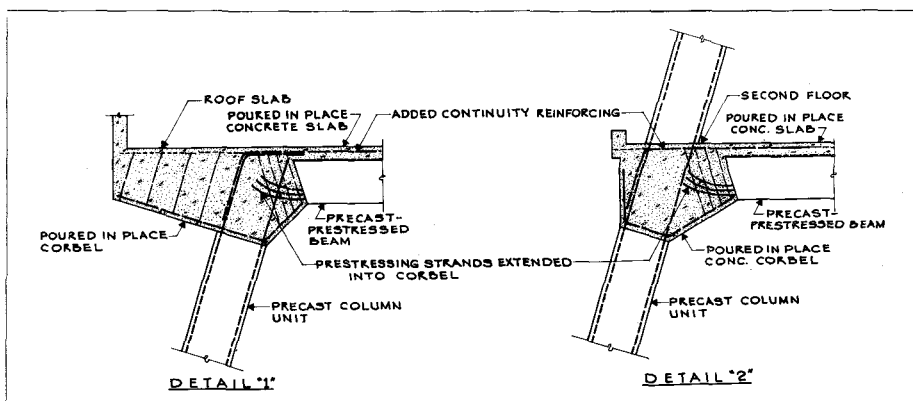


Fig. 16—Parking garage beam and column connections.

The garage structure then behaves like a multi-deck frame.

Column Trees

A recent development in precast framing systems is the "column tree" method as shown in figure 17. Columns with "branches" protruding out at each floor support line are precast. Each precast column supports several floors on its branches. Prestressed concrete beams rest on these "branches" and carry a poured-in-place deck slab which acts compositely with the beams. Lateral load resistance is accomplished by the deck slab acting as a shear diaphragm tying together all precast units and transmitting horizontal forces through shear walls of elevator and stair-well shafts to the foundation.

A typical precast "column tree" unit is shown in figure 18. The interior beam connection to the "branch" is shown in figure 19. The prestressed beams simply rest on "column branches" which have embedded steel dowels which are used to complete the connection. Strands from each beam are extended and continuity bars are placed in the slab area; the entire joint is concreted and all intersecting elements are then positively connected. Again, this joint extremely flexible to dimensional differences in the connected units while providing complete continuity and interaction.

The precast columns are connected to the footing by means of inserting the base into a concrete footing socket which is over-sized to allow lateral and vertical adjustment. Expanding grout is poured to fix the column base to the footing socket after the precast unit is carefully plumbed and positioned. Dimensional variations in the precast members can be accommodated without suf-

fering any field erection difficulties or loss in structural strength.

U.S.S. Arizona Memorial

In the field of long span construction, an interesting problem was encountered in the construction of a war memorial structure situated over the rusted hull of the battleship USS Arizona. This ship lies in its sunken position at the bottom of Pearl Harbor ever since December 7, 1941.

As shown in figure 24, the memorial structure calls for a total deck span of 184 ft. 6 in., and due to the extremely corrosive elements of salt water and mud, a prestressed concrete framing was selected. The width of the battleship was about 95 feet and being in a questionable structural condition, it was decided to clear span this entire width. Two piers 111 feet apart were constructed on prestressed, precast concrete piling.

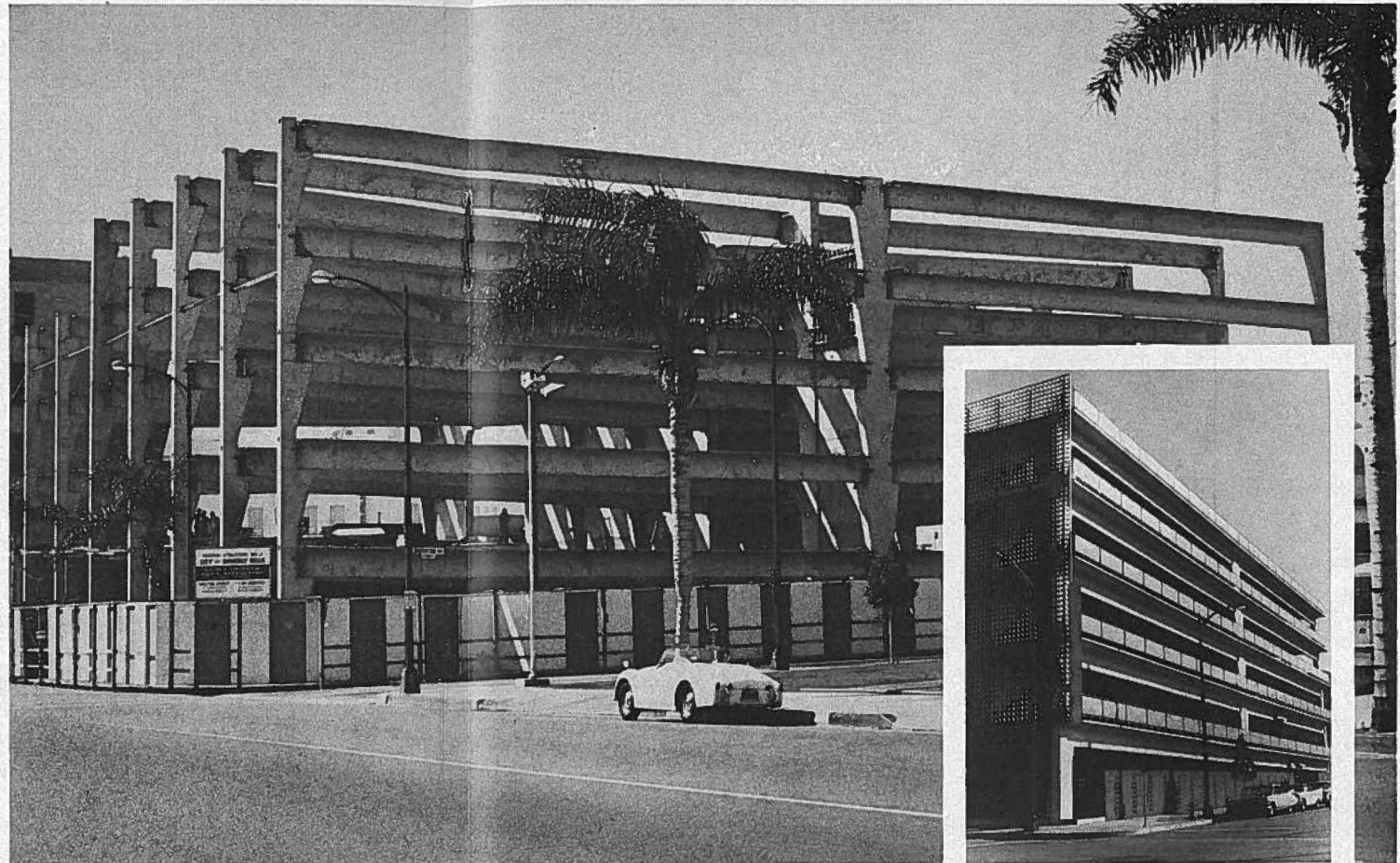
The deck structure was constructed of two post-tensioned girders 184 ft. 6 in. long. Since it was difficult to construct formwork and place materials over water more than 45 feet deep, it was decided to precast these post-tensioned girders for economy. Because of its size, each girder was cast in two pieces (figure 25) each piece weighing 138 tons and cast to a length of 89 ft. 3 in. A 6-foot wide gap was left at the mid-span where the precast pieces were temporarily shored onto the deck of the battleship. This gap was bridged by post-tensioned tendon sheaths and extended mild steel reinforcement before filling with concrete. After the concreted joint had gained sufficient strength, prestressing of the girders took place by means of post-tensioning and the temporary shores were removed later.

Again, in this situation the exact

Owner: City of Beverly Hills, Cal.; Architect: Welton Becket & Associates, Los Angeles, Cal.; Consulting Engineers: T. Y. Lin & Associates, Van Nuys, Cal.;

General Contractors: C. L. Peck, Los Angeles, Cal.; Ellis E. White Co., Los Angeles, Cal.; Precast Columns & T's: Walles Precast Concrete Corp., Sun Valley, Cal.

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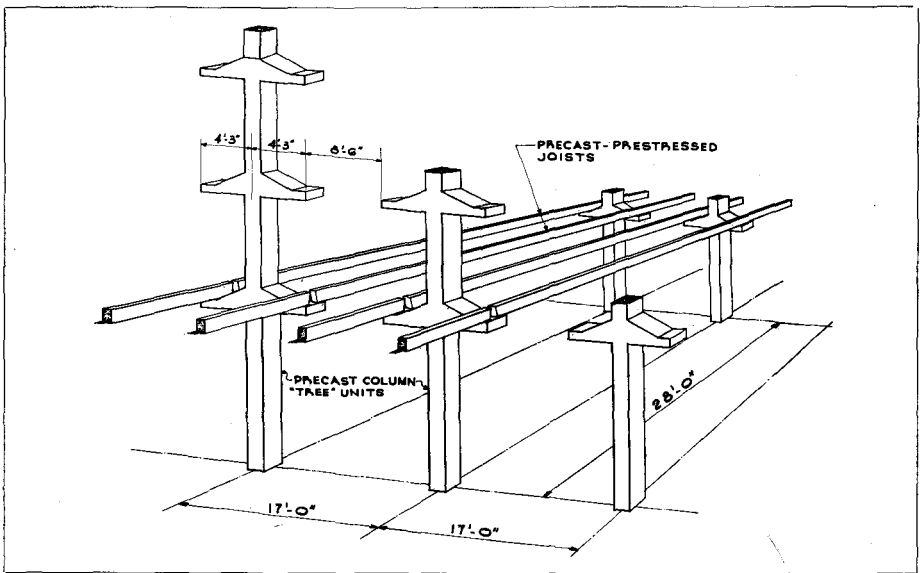


Fig. 17—The "column tree" framing system.

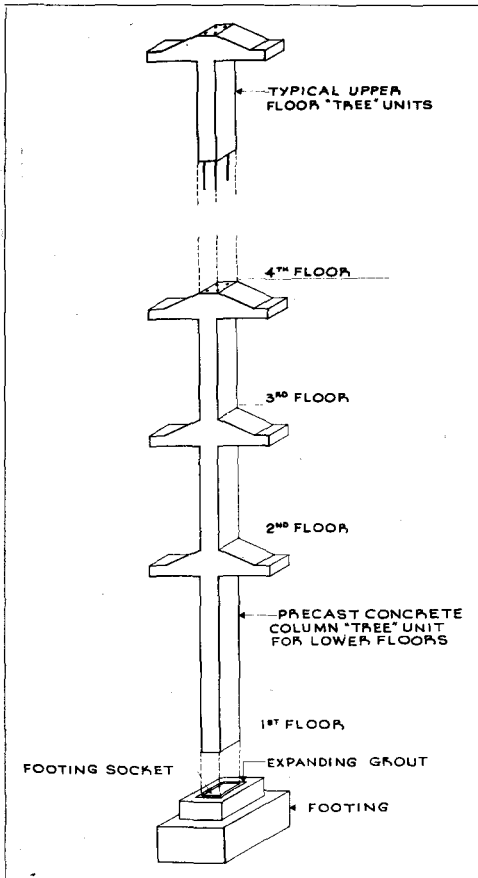


Fig. 18—The "column tree".

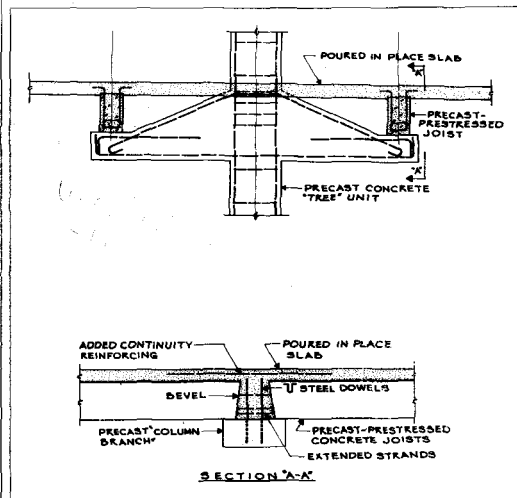


Fig. 19—Column tree connection between joists and "branches".



Fig. 20—Erecting first precast column tree.

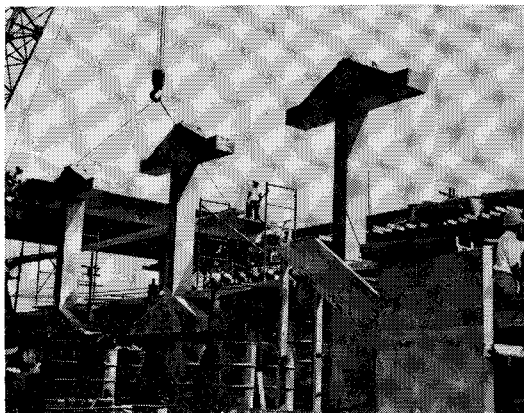


Fig. 21—Column tree framing system employing single Tee slabs. Construction took place over existing warehouse and laboratory facilities.



Fig. 22—Nearly completed building five weeks after lifting first column tree.

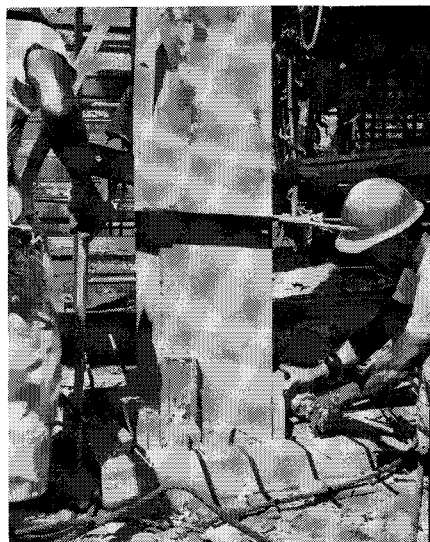


Fig. 23—Plumbing and positioning column base in socketed footing. Grout is poured in the space between the column and the footing to complete the connection.

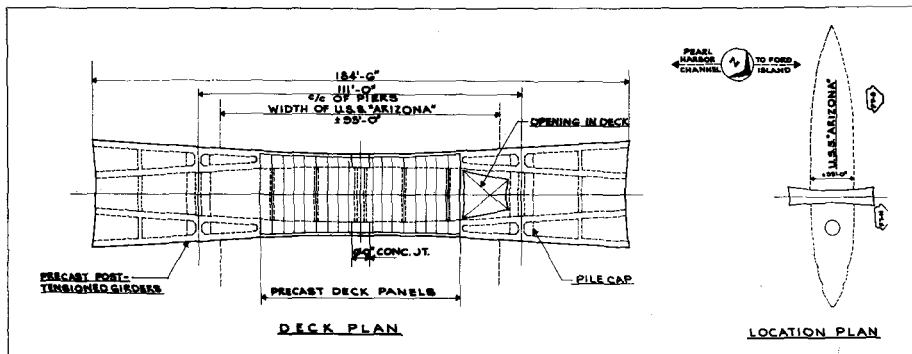


Fig. 24—Framing system for the USS Arizona war memorial structure.

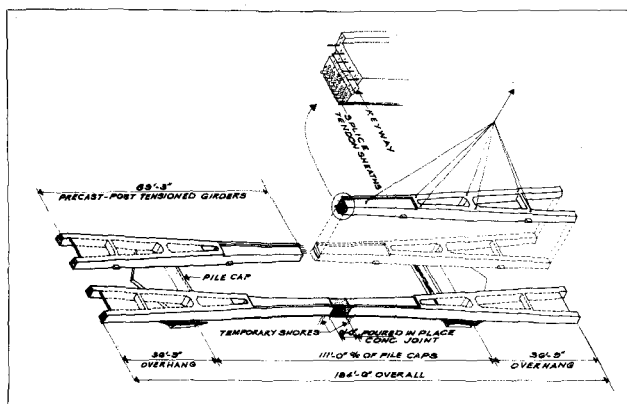


Fig. 25—War memorial structure; assembly and connection of precast units.



Fig. 26—Setting of half girder on pier and temporary mid-span shoring.



Fig. 27—Official U. S. Navy photograph. Mid-span joint completed and entire girder post-tensioned.

cast length of the precast pieces was not critical. All deviations were taken up by the 6-foot poured-in-place joint and full bearing was accomplished.

Precast pedestrian bridges

Several prestressed, precast pedestrian bridges were recently constructed in a golf course as shown in figure 28. Pretensioned, precast deck panels 4-feet wide by 38 ft. 3 in. long were erected at the site by resting on concrete piers and temporary shoring before pouring the counterweights. The prestressing strands were in a straight line pattern and extended out at one end to anchor down into the counterweight and at the other end to lap at the mid-span and develop positive moment. The counterweights and the mid-span gap were poured after the slabs were positioned which meant the poured-in-place concrete absorbed all dimensional variations. The bottom soffit of the precast slab was curved to follow the moment diagram and this allowed for production of these units with straight prestressing tendons.

Conclusion

Only a few examples of this versatile method of connecting precast members have been presented. It

is obvious that poured-in-place composite concrete connections can be used in many other areas of structural framing. We have only covered methods of developing continuity and interaction through embedded or extended reinforcing rods. It is also very convenient to develop this continuity and interaction through the poured joints by the use of post-tensioning. In such a case, again we find the advantage of the poured-in-place concrete connection, for it is in this section that we can adjust the position of the post-tensioning anchorages to suit the inadvertent variations of the tendons' sheath locations embedded in the precast members.

The poured-in-place composite concrete joint can provide full bearing and continuity between precast units regardless of possible dimensional deviations resulting from mass-production manufacture. Economy can be achieved by the elimination of costly metal hardware and inserts normally encountered by other types of joints. The human error factor involved in the placing of these items in the forms is likewise reduced. Nevertheless, these advantages should, in no case, be a justification for poor field or plant workmanship.

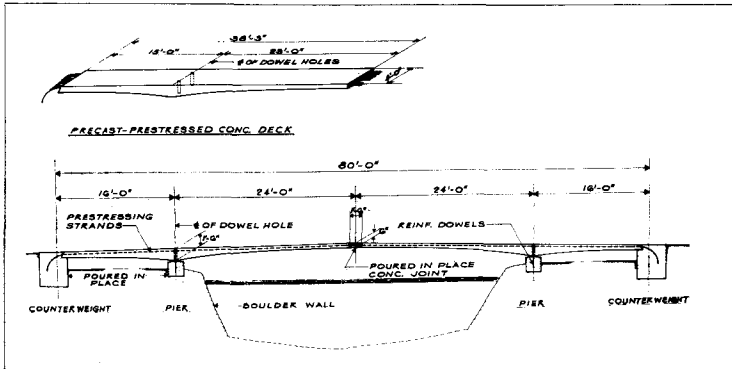


Fig. 28—Pedestrian bridge details.

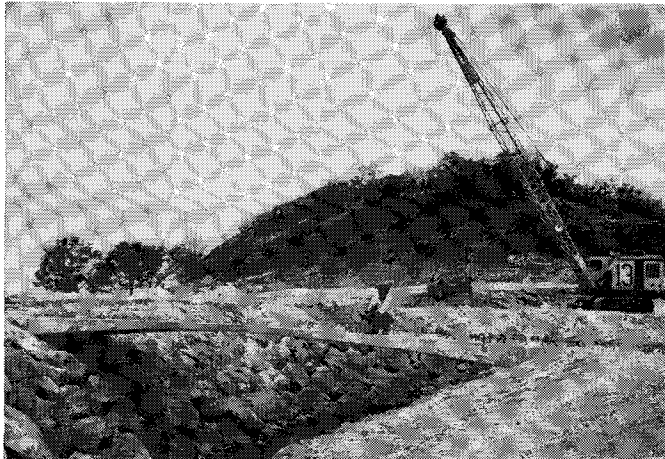


Fig. 29—Completed pedestrian bridge constructed by joining prestressed precast halves at the mid-span with composite poured-in-place concrete.