

Connections For Continuity

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Connections for continuity is an old subject which has been treated many times. So rather than plunge into another detailed description of the subject it will be approached from the standpoint of overall design.

In the design of larger more sophisticated structures, the use of standard products in the standard established way often falls grossly short of economic and engineering requirements. To answer the ever-growing requirements in aesthetics, functions, and economy, designs must be pushed beyond present horizons. For this purpose we combine all the tricks of the trade—

Precast with cast-in-place

Pretensioning with post-tensioning

Simple beams with continuity

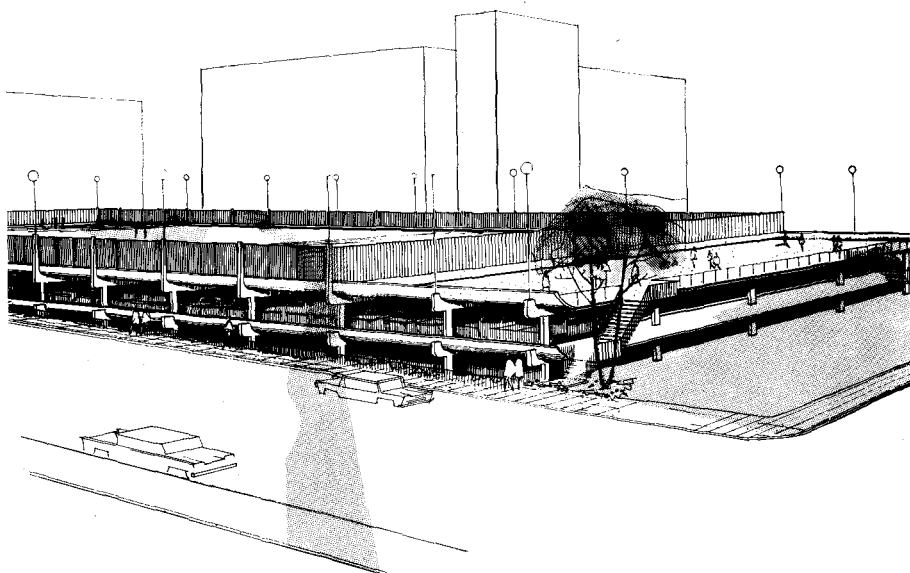
It is particularly the combination of simple beam and continuous member which constitute a potent tool for good creative structural design in prestressed concrete. Continuity is achieved in many ways. The well-established methods of using reinforcing bars or the use of welding has been thoroughly covered in other papers. Post-tensioning or the use of high tensile strength bolts provide another means of achieving continuity. As an illustration, a building using the post-tensioning method to attain continuity will be discussed in this paper. It is interesting because it involves a number of design features which

are indicative of the success to be achieved by combining the various aspects of the prestressed concrete industry.

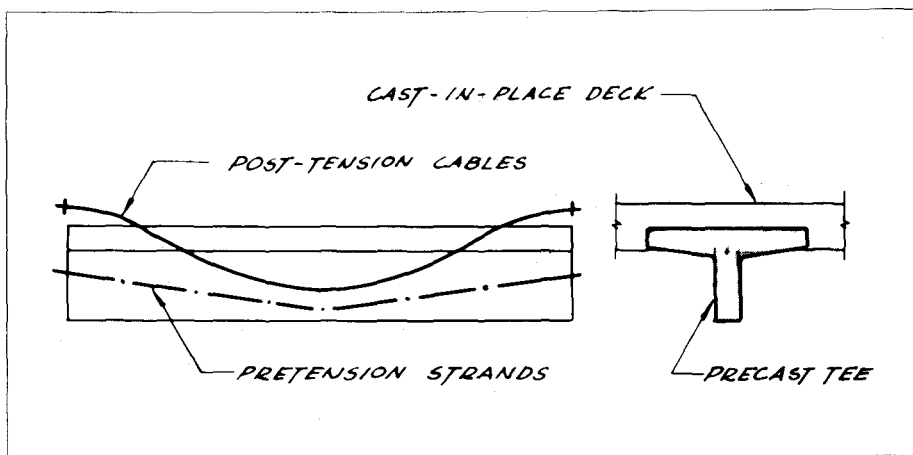
The structure is the Parking Structure D for the University of California at Berkeley, California. It is a significant structure from a number of standpoints:

- I Design-wise it is interesting, inasmuch as it accommodates a playfield on the third level. This imposes an actual super-imposed load due to the earth fill of 200 psf, and requires the deck to be entirely waterproof.
- II Construction-wise it embodies a variety of concrete products such as precast girders, both pretensioned and post-tensioned, a post-tensioned deck, and precast, conventionally reinforced columns.
- III Economy-wise it is most significant. The structural design was carried out two ways: conventionally reinforced, cast-in-place construction and precast, prestressed construction with long spans. On the basis of the first costs, the savings in precast, prestressed over cast-in-place construction was in the neighborhood of 6%; however, on a per-car cost, the savings went up to 14%. This was due to the increased parking capacity for the long-span scheme.

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Rendering of the parking structure. Garage has a capacity of 750 cars with an athletic field on top.



Drawing of typical precast prestressed girder.

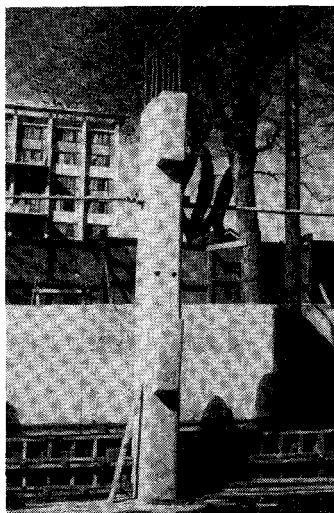
The structural components of the garage consisted of precast columns and girders and cast-in-place floor decks. The girders, spanning 63 feet between columns, were pretensioned for erection purposes and post-tensioned in place for the final load. The post-tensioned slab is six and one-half inches thick and spans 24 feet between the girders.

The construction procedure for the superstructure can be divided into three overlapping phases: (1) erection of the columns and girders, (2) casting the floor decks, (3) post-tensioning the decks and girders. Each of the three phases was handled twice for each level. The center two bays were completed first. Once these bays were post-tensioned and completed the outer bays were erected. Not shown in the schematic drawings on page 52 is the shoring which was necessary underneath the girders before they were post-tensioned.

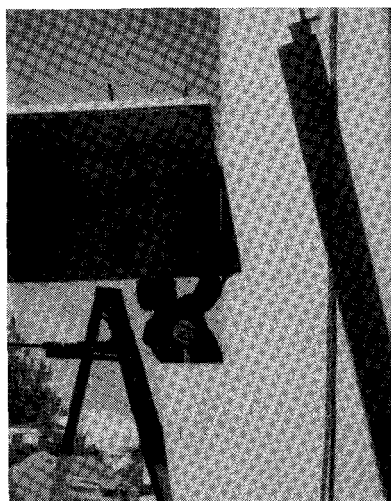
Columns for bays B-C and C-D were erected and the girders were placed on the column corbels, which had locating dowels cast into them. Erection of the girders for the roof and floor, in the center portion of the building only, completed the first phase.

Next, couplers had to be inserted at column lines B, C, and D before the deck was cast and post-tensioned. Great care was necessary in locating the post-tensioning cables accurately so that they would match in the field. The tolerances were rather close, and mistakes could have been fatal.

The jig used for locating the post-tensioning tendons in the girders is shown on page 53. Five tendons were placed in the girders supporting the heavy loads imposed by the athletic field. Connections for this



Erected column.

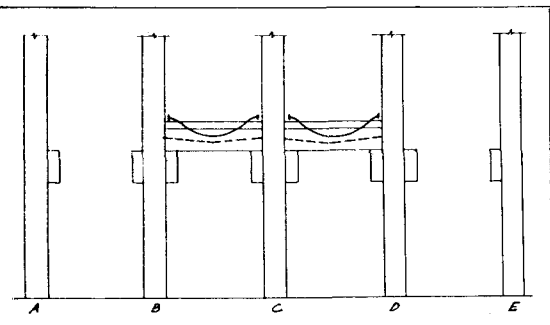


Girder being placed on column corbel. Notice locating dowel.



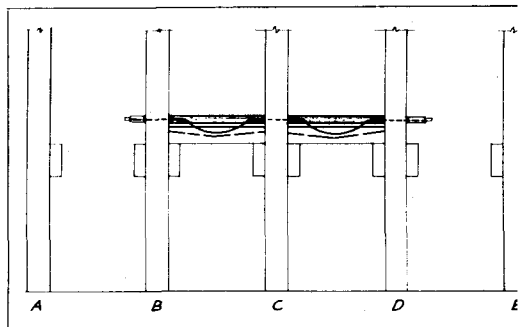
Structure after columns and girders had been erected.

Series of schematic drawings illustrating the steps in the construction procedure.

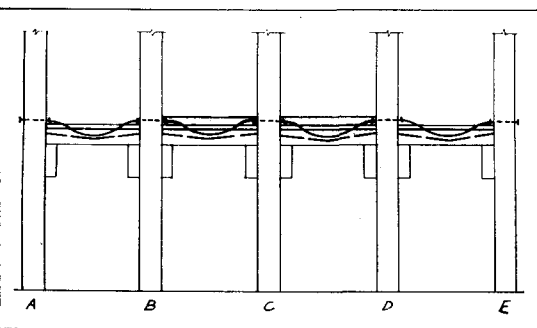


a. Girders and slab in place in center span only.

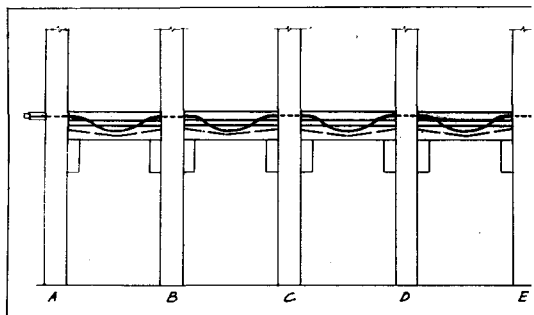
b. Post-tensioning center span.



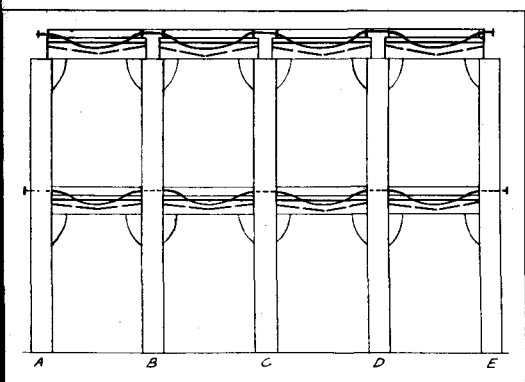
c. Girders and slab in place in exterior span.

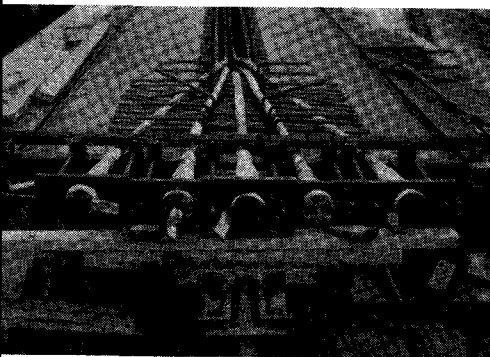


d. Post-tensioning spans completing lower level.



e. Completed upper level. Same construction procedure as lower level.





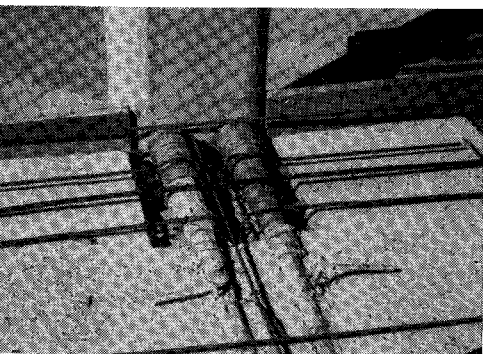
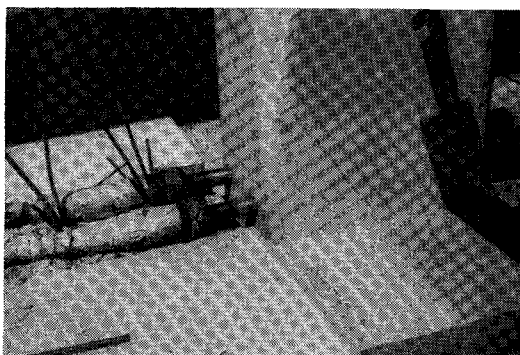
Jig for placing post-tensioning cables in girders used for upper levels.

View at ports in column before couplers were placed.

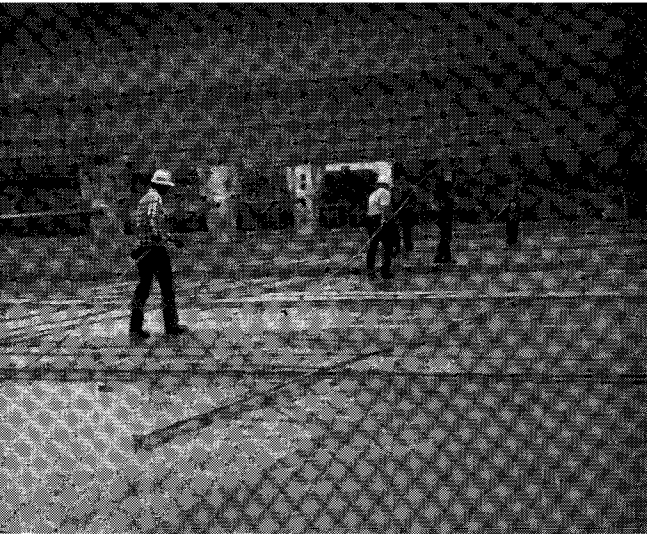


View of connection between post-tensioning cables of two girders.

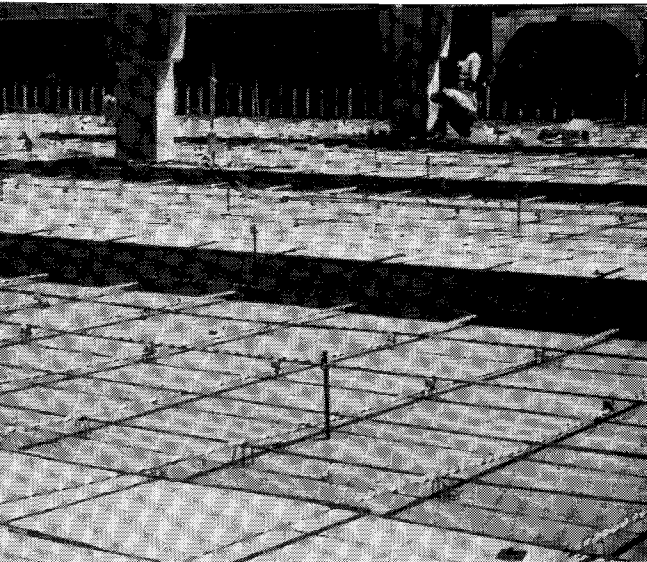
View of connection between couplers and post-tensioning cables in girder at dead end.



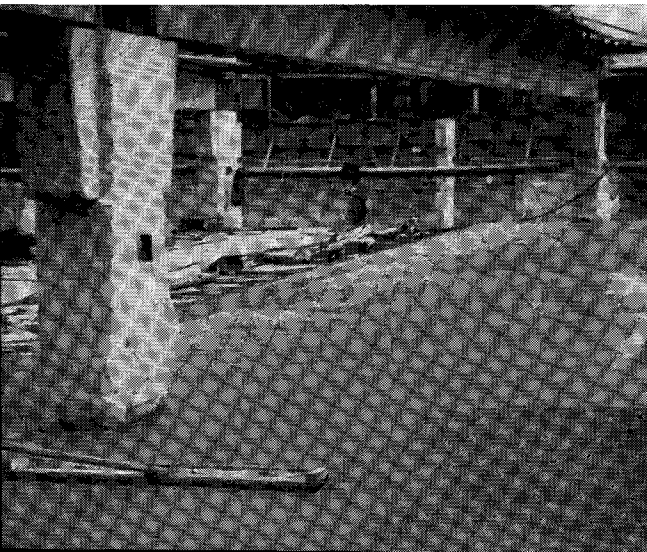
View of covering for stressing washer. Covering allows movement of washer during stressing.



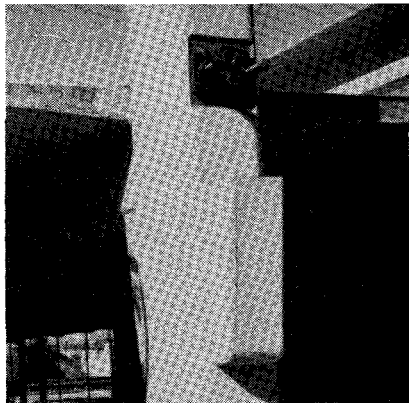
Workmen placing tendons used in post-tensioning slab.



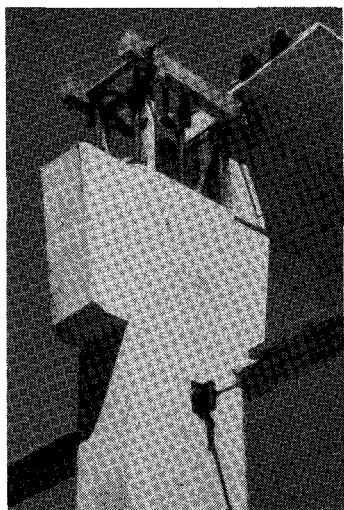
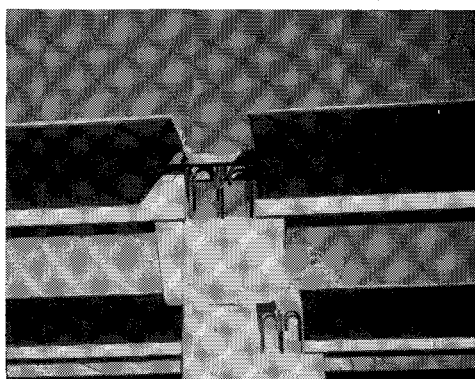
Slab tendons in place preparatory to pouring concrete.



Once slab has set the girders and slab will be post-tensioned. Camber control and continuity are achieved using this construction sequence.

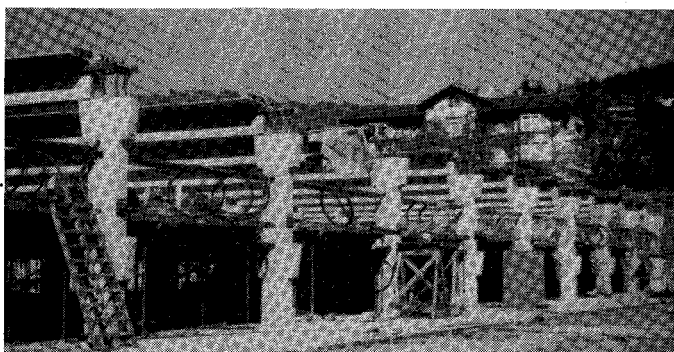


Typical detail of connection at dead end of an interior column.



Photos show column-girder connection at second level. Notice the five tendons in the girder necessary to handle heavier loads imposed by athletic field.

Completed center bays for lower level.



level were much easier since the tendons did not have to pass through ports in the column. Girders in the lower level required only two post-tensioning tendons.

Photographs on page 53 illustrate the coupling mechanism, and the protection provided for the stressing washer permitting movement during stressing. The holes in the columns through which the high-tensile strength rods passed also had to be located extremely accurately to match the girder tendons.

With the couplers positioned and the girder post-tensioning tendons placed, the next step was to erect the floor decks. Forms and post-tensioning tendons for the slab were erected. The slab was then poured and post-tensioned.

Upon completion of the post-tensioning of the slab, the girders were stressed. Post-tensioning the girders at that point permitted the camber to be controlled as well as achieve the desired continuity.

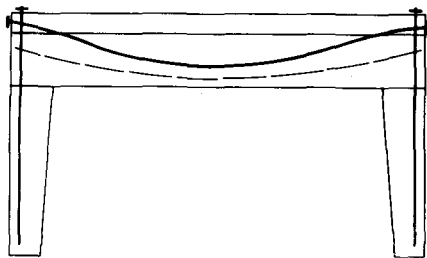
The first series of the garage construction phases is now completed. Efforts were now turned to working on the outer bays, A-B and D-E. Construction of the outer bays was a repetition of the work already completed on the center bays.

Other structures have been constructed in somewhat the same manner, the most notable of which is the seven story Beverly Hills Garage.

The schematic drawing on this page illustrates a combination of vertical as well as horizontal post-tensioning. This method was used in several structures including the Telecomputing Building in California.

Once the girders are post-tensioned the vertical steel is stressed and the joint dry-packed providing a fully moment resistant connection.

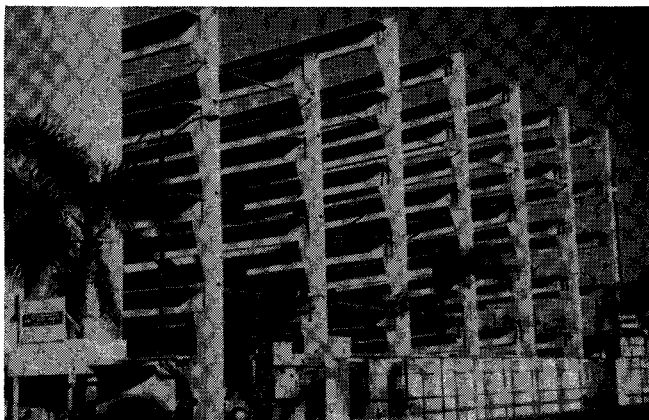
To obtain proper connection de-



Schematic drawing of system utilizing vertical post-tensioning to create moment resistant connection.

tails the designer must keep in mind that no two structures are the same, and each has its own problems. Extreme caution should be taken not to use details which do not fit the conditions of a particular structure.

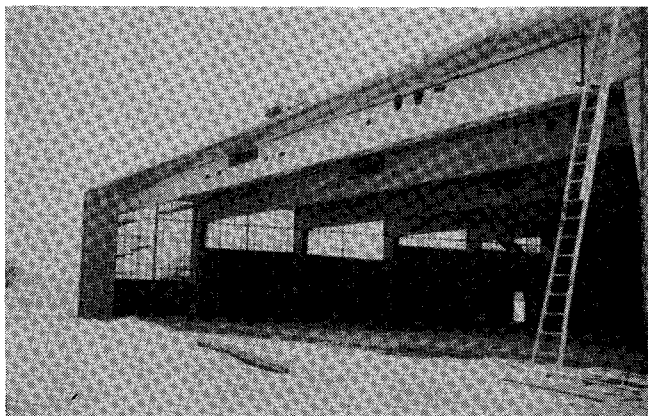
Achieving continuity, both in design and construction, is not an easy task. In the design, particularly, great care must be taken to balance loads, analyze all possible contingencies and detail connections based on experience and ingenuity. Why should continuity be used in the first place? If the parking problem is to be solved in the large cities, engineers must provide the long spans to do it with—and to provide long spans, continuity is an invaluable aid. If the over-crowded cities need tall buildings to solve the problem of overpopulation, it can be done cheaper and better with a continuous prestressed concrete structure. If the conditions of high winds and earthquake present difficult problems, these problems can be hurdled with prestressed concrete continuous frames. The construction industry has a wealth of good products for engineers to use, so it stands to reason that it is up to the structural engineering profession and particularly to those engineers who deal with the design of prestressed concrete, to join these products in a manner which will make truly great structures.



Seven story parking garage in Beverly Hills, Calif.



Details of stress steel rods in column prior to post-tensioning. Wires at top of photo are tendons used to post-tension slab.



Girders of Telecomputing building in Los Angeles, Calif. Vertical post-tensioning was used in this structure. Skillful design permitted many holes for ducts and pipes to be placed in stems of the girders.