Presents the highlights of the recent United States-Japan Seminar on Precast Concrete Construction in Seismic Zones from two viewpoints. In the introductory part, Professor Neil M. Hawkins gives an overview of the Seminar together with the principal findings from the conference sessions. In the second part, Dr. Robert E. Englekirk offers his impressions of the Seminar from a design engineer's viewpoint.

U.S.-Japan Seminar on Precast Concrete Construction in Seismic Zones

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Overview of Seminar

by NEIL M. HAWKINS

The fifth American Concrete Institute-Japan Concrete Institute Seminar on Concrete was held in Tokyo, October 27 through November 1, 1986. The subject of the Seminar was Precast Concrete Construction in Seismic Zones.

On the United States side, the Seminar was supported financially by the National Science Foundation, Division of International Programs; and the Prestressed Concrete Institute. On the Japan side, the Seminar was supported by the Japan Society for Promotion of Science, the Japan Precast Concrete Contractors, and many other construction related organizations. Additional technical support for the Seminar was provided on the United States side by the American Society of Civil Engineers and on the Japanese side by the Architectural Institute of Japan and the Japan Society of Civil Engineers.

There were 12 United States delegates drawn from consulting firms, precasting organizations, and universities, headed by Professors Neil M. Hawkins and Alan H. Mattock from the University of Washington. Other United States participants were Dr. Samy Adham, Agbabian and Associates, Los Angeles; Professor Ned H. Burns, University of Texas at Austin; Dr. Douglas P. Clough, ABAM Engineers, Seattle; Dr. Robert E. Englekirk, Robert Englekirk Consulting Structural Engineers Inc., Los Angeles; Professor Harry G. Harris, Drexel University, Philadelphia; Professor William L. Gamble, University of Illinois; Mr. Francis J. Jacques, Stanley Structures, Denver; Professor Peter Mueller, Lehigh University, Bethlehem, Pennsylvania; Professor John F. Stanton, University of Washington; and Dr. Alfred A. Yee, Honolulu. Six of the American delegates were accompanied by their wives.

On the Japanese side, there were 16 delegates drawn from the same mix of organizations as on the United States side, headed by Professor Yasuyoshi Suenaga of Yokohama National University, and assisted by Professor Jun Yamazaki of Tokyo Metropolitan University. While an unfortunate illness prevented Professor Suenaga's attendance at the Seminar, the depth of his planning was demonstrated by the success of the Seminar and the ease with which Professor Yoshikazu Kanoh from Meiji University and Professor Sigeru Mochizuki from Musashi Institute of Technology could step in and take leadership on the Japanese side.

In addition to the American and Japanese participants, there were five Third Country participants drawn from Canada (Professor Richard Spencer); People's Republic of China (Mr. Wei Lian); Mexico (Professor Francisco Robles); New Zealand (Professor Robert Park); and Norway (Mr. Per Jahren).

The Seminar was divided into three phases so that events were consistent with supporting agency constraints. The majority of the United States and Third Country papers were presented at a two-day long pre-Seminar attended by some 250 Japanese engineers and held in the auditorium of the Architectural Institute of Japan. The remaining American and Third Country papers and the Japanese papers were presented at a three-day long closed Seminar held in the offices of the Japan Society of Civil Engineers.

Finally, the Seminar concluded with a four-day post-Seminar tour that included a survey of construction for the widening of the Tohmei Expressway linking Tokyo and Osaka, and a visit to the second Honshu-Shikoku Bridge Crossing. There was also an active social program: a conference banquet involving a welcoming reception at the pre-Seminar in Happoen and a farewell reception at the Fujiya Hotel in Hakone.

In the technical program some 45 papers were presented of which 12 were state-of-the-art reports; 6 were earthquake response reports; 10 were concerned with members' properties for earthquake loadings; 5 with joint properties for earthquake loadings, and 12 with mixed gravity and earthquake use considerations as likely with bridge decks, girders and off-shore structures. The more significant contributions will be included in a Special Publication to be produced by the ACI. The following are the principal findings from the Seminar:

1. Information on the actual dynamic response of precast concrete construction in earthquakes is lacking and, thus, there is inadequate correlation between computer predictions of dynamic behavior and actual behavior.

2. Japanese investigators have been concerned primarily with what occurs between interfaces, while non-Japanese investigators have been much more concerned with what happens on each side of the interface. There is a need to integrate the results of the two programs so that future investigators can use the understanding generated by both programs.

3. There is much more interest in possible bridge structure innovations in Japan than in the United States. Much of that Japanese effort is directed towards possible precast concrete bridge deck developments while the primary American concern is with bridge deck durability.

4. In Japan, precast prestressed concrete structures are essentially an extension of concrete structures in general and the overall design objective can be described as attempting to make precast concrete structures behave as monolithic structures. The exception is low-rise housing structures where adjustments in design loads are permitted when there is laboratory documentation of the available ductility. By contrast, in the United States, because of the differing seismic zones, details have been developed for precast prestressed concrete that differ from those for monolithic construction. In the United States, the primary emphasis is on readily constructible, dry joints. Technological advancements could result from the marrying of these two concepts.

5. Over the last decade, in both Japan and the United States, the prime interest for precast concrete construction in seismic zones has shifted from panel structures to frame structures. For precast prestressed concrete frame structures, there is a need for a code compatible research program that examines the significance of variations in global ductility forms on dynamic response and the interrelation between such global ductility forms and ductility response characteristics. The significance of variations in the area and shape of the hysteresis loops for reinforced concrete versus partially prestressed concrete, versus prestressed concrete structures, versus other material forms needs to be examined through correlation of theoretical studies, shaking table data and real earthquake data.

In conclusion, this Seminar on Precast Concrete Construction in Seismic Zones was two years in planning. It was officially part of the ACI-JCI Seminar Program and the U.S.-Japan Scientific Exchange Program. It is hoped that the follow-up to this successful international conference will also include NSF-JSPS funding of a joint research program on precast construction in seismic zones.

Designer's Viewpoint of Seminar

by ROBERT E. ENGLEKIRK

The importance of exchanging design and construction ideas cannot be overemphasized. Though there may exist enough difference in our respective construction industries and social goals to preclude a direct system transfer, the ideas conceived by designers to effectively develop systems are readily transferable.

In the overview which follows, an attempt has been made to focus on supporting ideas and concepts in the hopes that the reader will not summarily dismiss a system but rather endeavor to understand the supporting ideas and introduce them into our construction industry. Many intriguing concepts were presented at the United States-Japan Seminar on Precast Concrete Construction in Seismic Zones and subsequently discussed.

Several parallel trends exist in the marketplace for precast concrete in Japan and the United States. The industries of both countries appear to be emerging from a long period of inactivity where the economies of cast-in-place concrete severely reduced the structural market share of precast concrete. Both countries appear to understand the direction required of precast concrete if it is to once again become a viable product.

Japan, however, is significantly ahead of the United States in terms of developing the tools necessary to implement the supporting program. The Japanese recognize the importance of a systems approach, wherein the amount of precast concrete is maximized. As a consequence, their tests have focused on assembly methodologies which give the constructor the flexibilities necessary to embark upon an imaginative and cost effective use of precast concrete.

Further, though the composition of the construction industries in the United States and Japan appear at least superficially to be significantly different, many basic similarities exist. Large Japanese constructors utilize staff engineers and architects to develop building designs which they market on a turnkey basis. This does not, however, represent the major part of their work for the community of independent consultants is reported to be three or four times larger than that employed by constructors.

Since the effective development of precast concrete systems requires a team approach, the designer and constructor must combine their talents and backgrounds if a well designed, cost effective system is to be developed. The Japanese system is well suited to this process and has, as a consequence, produced some challenging precast prestressed systems.

Many American constructors are promoting with considerable success the design/construct approach to project development. As a consequence, more imaginative precast prestressed concrete systems are being developed and refined in the United States. The rate of development is considerably slower than in Japan as will readily be seen in what follows.

Fundamental Considerations

The quantification of ductility demands and availability of ductility in precast concrete systems is basic to any engineering decision relating to seismic design. A simple method for quantifying component ductility demand was presented by Clough.[1] Clearly, connector location and the ductility demand placed on the connector plays an important role in the evaluation of systems.[2] Three basic connector/deformation conditions are characteristic of precast concrete systems:

(a) Precast concrete connections which require post yield deformation capabilities or energy dissipation.

(b) Precast concrete connections in which stress demands are high but elastic behavior is anticipated.

(c) Precast concrete connections in which moment demand is low.

Examples of Type "a" connectors are typically those which occur in beams at the beam-column interface and those located at the base of a shear wall. In the United States neither code nor practice accepts connectors or splices in beams or columns of ductile frames if post yield deformations are likely. On the other hand, joints in precast wall panels are accepted regardless of whether or not they possess any ductility.

The Japanese Code permits the designer/constructor considerably more freedom. The design proposed must be shown to possess acceptable levels of ductility. The Japanese have developed a procedure for prequalifying connectors which are to be used in regions of stress reversal where the connector must be capable of post yield deformations. The design proposed must be shown to possess acceptable levels of ductility. As a consequence, the Japanese Code permits this type of connection.

Acceptability is accomplished through the prequalification of subassemblies proposed for a project. Japanese prequalification procedures require four cycles of strain to $2\,\epsilon_y$ and $5\epsilon_y$.[3] Japanese codes prescribe higher yield load levels and, as a consequence, ductility demands will be lower than those anticipated in United States

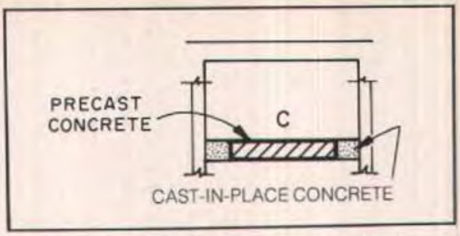

Fig. 1. Precast unit in frame system.

codes. Most of the participants felt that a standardization of test programs which identified post yield load level and the number of cycles at that load level would facilitate technology transfer.

Connections most commonly used in Japan on ductile frames use a cast-in-place joint.[4] From a philosophical perspective, the joint shown in Fig. 1 (taken from Ref. 4) is of particular interest. Whether or not an assembly of this type has been tested was not clear. Presumably the adverse implications associated with performance and constructibility have discouraged extensive testing of this system. Of significance, however, is the fact that it is not categorically forbidden and if a contractor were to demonstrate an acceptable level of available ductility in this assembly, it could be used and the reinforcing bar splice accepted, presuming it had been prequalified.

Discussions focused on the hysteretic behavior of connectors subjected to cyclic loads significantly beyond yield. The importance of the shape of the hysteretic loop must be established. Precast concrete joints are characterized by pinched hysteresis loops and, as a consequence, presumably dissipate less energy than cast-in-place assemblies even though curvature and displacement ductilities are comparable (Fig. 2).

The Japanese felt that energy dissipation was the key to comparability while New Zealand and United States participants considered ductility as measured by deformation to be most important and

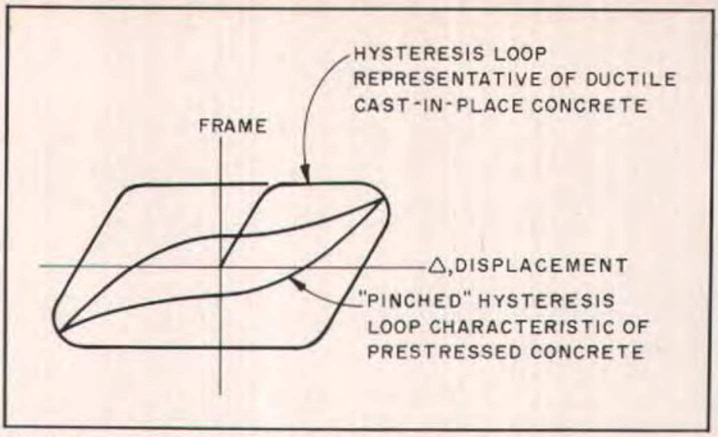

Fig. 2. Hysteretic behavior of concrete systems.

energy dissipation not a significant issue. Clearly, work in this area is of paramount importance if joints in precast assemblies are to be located where yielding is anticipated since the pinched hysteresis loop is a characteristic feature of these assemblies.

Precast Concrete Applications

Joints in regions of high stress do not appear to concern Japanese engineers as much as they do engineers in the United States. This is evidenced by the fact that Japanese engineers have constructed frame buildings of up to 24 stories[5] using precast beams and cast-in-place columns. All column reinforcing steel is spliced immediately above the beam-column joint (Fig. 3).

Constructibility requires that the embedment of beam bars in the beam-column joint be reduced significantly from what is considered acceptable by United States codes. Beam joints that further reduce the splice and embedment length (Fig. 4) have been prequalified for low rise buildings.

Ohbayashi-Gumi Corp.,[5] in the construction of a 24-story apartment building, elected to use a longer precast unit continuous through one column and spliced at midspan with an adjoining precast segment (Fig. 5). Bottom bars were continuous through one joint while at the discontinuous beam end the reinforcing steel was continuous with a 180 degree loop connecting top and bottom bars. Top bars were then placed in the poured topping slab. Slab units were precast. Columns were spliced above the floor, all bars being welded at this point. A floor cycle was accomplished every 8 days (6-day work week). Columns were spaced at 15 ft (4.6 m) centers [12 ft (3.7 m) clear].

Taisei and Shimizu have constructed 3,840,000 and 240,000 sq ft (357,000 and 22,300 m^2), respectively, using a variety of precast/poured systems utilizing precast column forms, beam shells or half beams and forming slabs. Recent American experience in areas of comparable seismicity is limited and typically does not use precast components to the extent used by the Japanese.[6,7]

Using post-tensioning to assemble precast concrete units in Japan is accepted. Low rise housing units comprised of precast units may be assembled using post-tensioning but more often appear to be assembled using

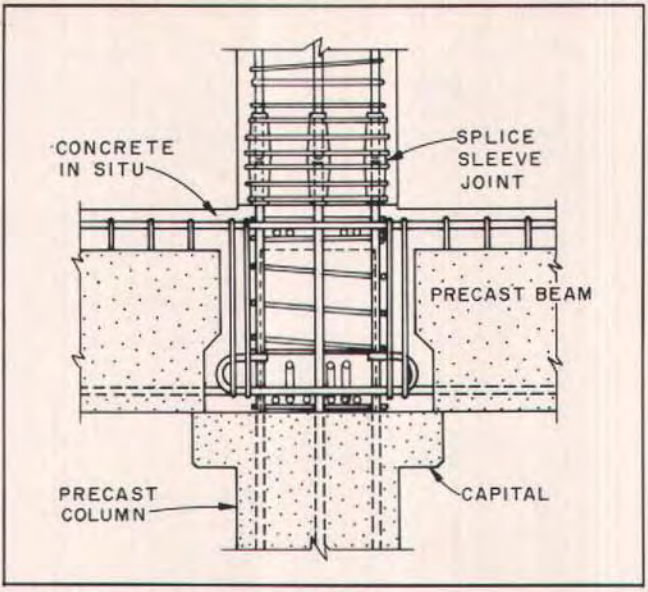

Fig. 3. Panel zone of column beams.

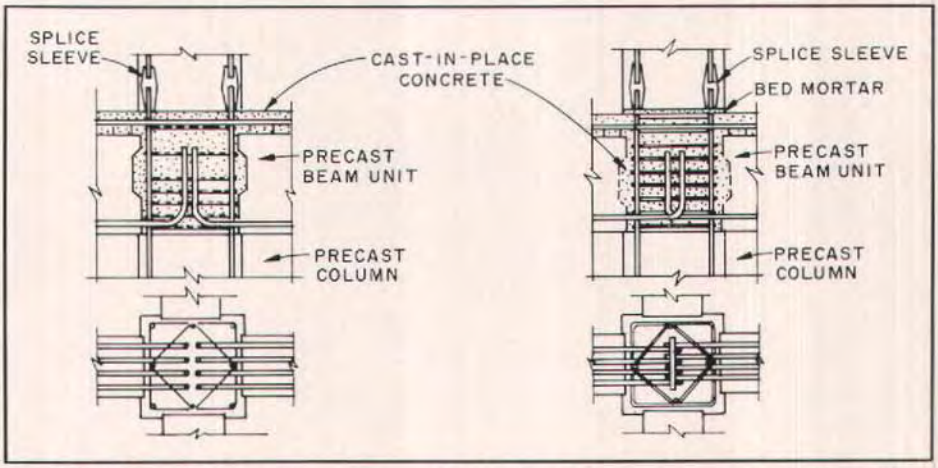

Fig. 4. Left: Type A for buildings with small stress (two to three stories). Right: Type B for buildings with large stress (four to seven stories).

bolts. Housing units of up to 10 stories[8] [102 ft (31 m)] may be joined using post-tensioning or splice sleeves. Special boundary elements typically required by current United States codes do not appear to be the practice.[9] Wet joints with hoop connectors are common (Fig. 6) although dry joints are also used (Fig. 7).

The area of wet concrete transferring

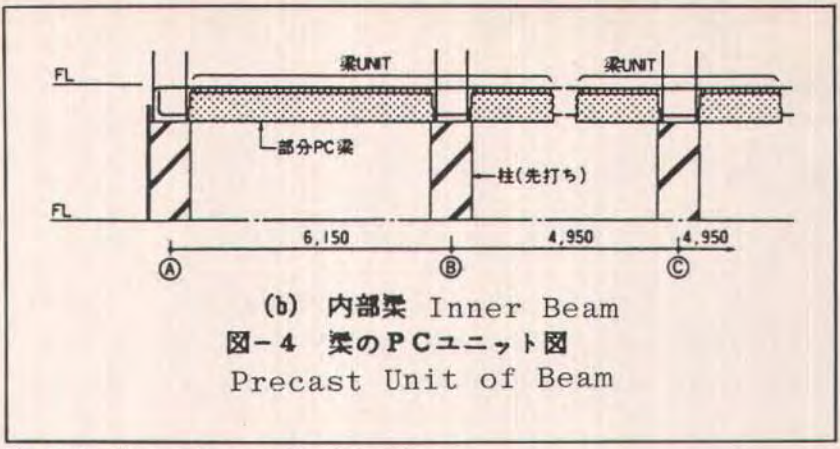

Fig. 5. Continuous beam spliced at midspan.

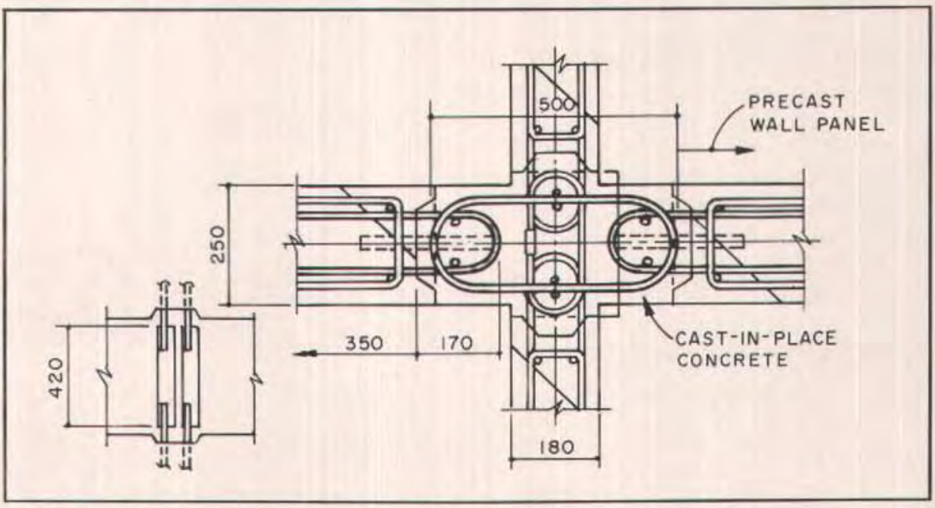

Fig. 6. Example of wet joint (eight stories) (Ref. 9).

shear from panel to panel does not appear to concern either the Japanese or American research group (see Fig. 8).[9] Shear transfer mechanisms permitted by current United States codes require the use of shear friction (at least by usual interpretation). As a consequence, the throat area and quantity of reinforcement crossing this joint is larger than appears to be required.[10]

Professor Park (New Zealand) presented a report on joining precast concrete frame members with grouted post-tensioning.[11] Limited testing, now over 15 years old, indicates good behavioral characteristics within the region of plastification which appears to be only slightly smaller than that which occurs in comparable cast-in-place systems.

Tests performed at Lehigh University (as yet unpublished) indicate that the

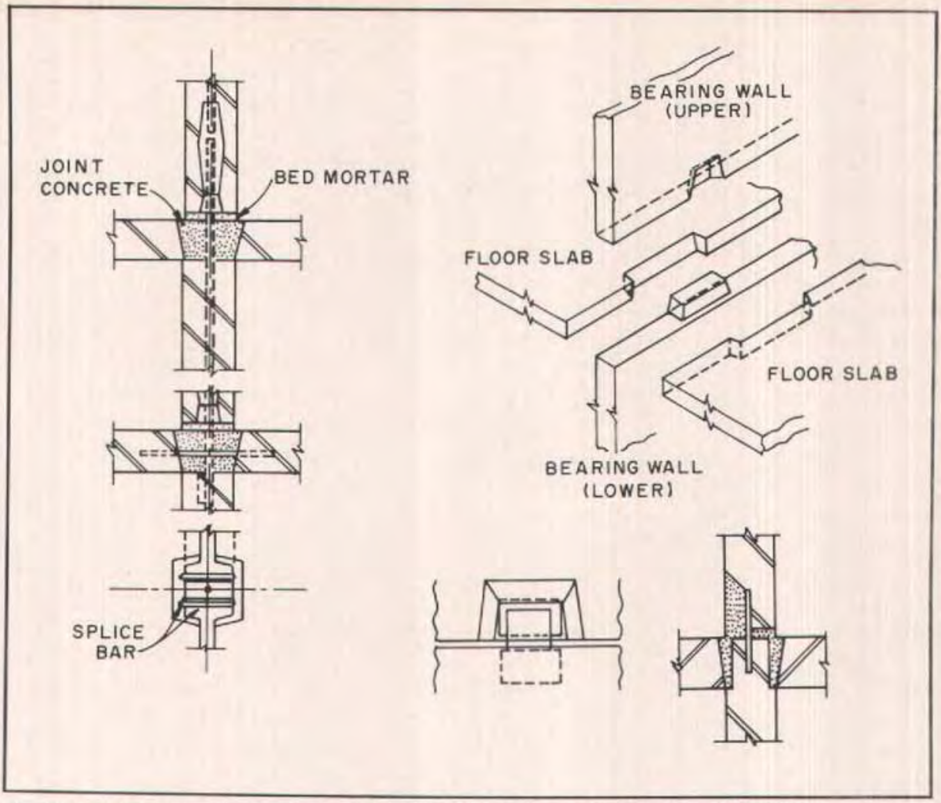

Fig. 7. Left: Dry joint (splice sleeve) (Ref. 9). Right: Dry joint (SPH type) (Ref. 9).

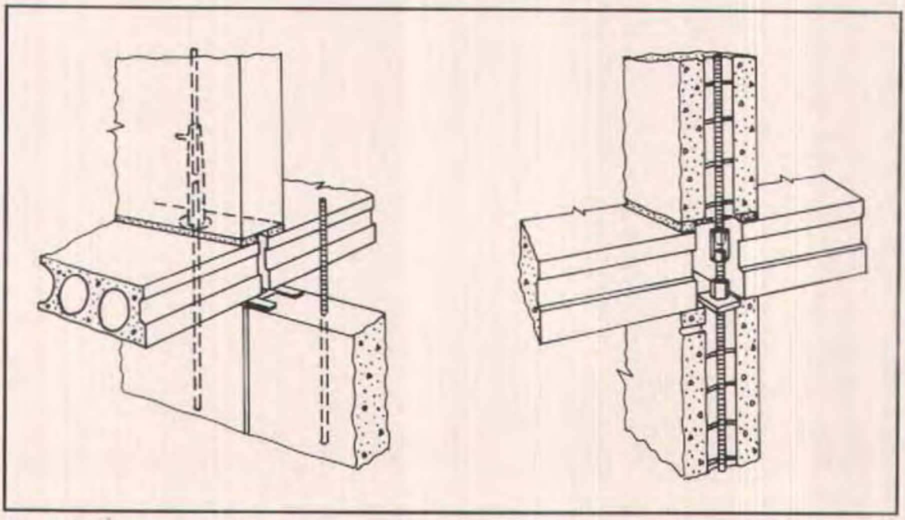

Fig. 8. Platform type horizontal connection with Grade 60 reinforcement (left); and post-tensioning bars (right).

performance of precast concrete wall systems joined with MTB splice sleeves is comparable to the performance of cast-in-place systems. Significant improvement has been observed in connection with the inclusion of spiral confinement reinforcement of the splice sleeve.

Joining precast concrete components with epoxy and post-tensioning is being studied in Japan.[12] If post-tensioning levels are reasonably high [600 psi (4.1 MPa)], joint behavior appears to be comparable to cast-in-place construction. Test programs planned by both Japanese and New Zealand researchers will use epoxy based grout joints approximately 1 in. (25.4 mm) thick to connect precast members' joints by post-tensioning. Japanese tests will probably focus on shear transfer while New Zealand tests will be concerned with cyclic behavior of joints in the post-elastic range.

Precast concrete floor slabs have been assembled with post-tensioning in Japan. Composite action between precast concrete slabs, joined by post-tensioning, and steel supports has also been accomplished.[13] Bridge decks of precast slabs (noncomposite) supported by prestressed girders have been used by the Japan Highway Public Corporation.[14] Diaphragm shears were attained with grouted shear keys and post-tensioning.

Conclusion

Development of a methodology for the design of precast concrete to resist seismic loading is well underway in Japan as evidenced by the publication of the new Japan Code governing precast concrete construction. [Unfortunately, this document (Ref. 15) has not been translated into English.]

American procedures are still in the conceptual stages[6] though ideas and imaginative use of precast concrete in areas of moderate seismicity abound.[16,17]

Quality control, construction economies, and speed of construction make the effective use of precast concrete as a seismic bracing element a desirable goal. A cooperative effort is the most cost effective way of accomplishing this objective.

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NOTE: Discussion of this joint article is invited. Please submit your comments to PCI Headquarters by December 1, 1987.

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