Proposed Design Requirements for Precast Concrete

Prepared by

PCI Committee on Building Code

and

PCI Technical Activities Committee

Based on initial drafts by Irwin J. Speyer, consulting engineer

This document contains proposed code provisions for the design of structures incorporating precast concrete members. The provisions apply to precast products which are either prestressed or nonprestressed. The report is divided into two parts: (1) Recommendations and (2) Commentary. Emphasis is focused on items that apply particularly to precast concrete construction and which supplement or differ from the ACI Building Code. Among the topics covered are floor, roof and wall panel systems, connections, identification and marking of components, time dependent effects, transportation, storage and strength evaluation of existing precast structures.

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PREFACE

In 1981, the precast and prestressed concrete industry decided to prepare a document containing design requirements for precast concrete. A consultant, Irwin J. Speyer, was engaged to prepare an initial draft, after which it went through a number of reviews by the PCI Committee on Building Code. PCI also had the cooperation and joint involvement of the National Precast Concrete Association and the Architectural Precast Association. The intent was to prepare a document for consideration by ACI Committee 318 in revising code provisions for precast concrete.

By early 1984, a fifth PCI draft in code and commentary format, offered as a proposed revision to the ACI Building Code (ACI 318-83), Chapter 16, Precast Concrete, was submitted to ACI-ASCE Committee 550, Precast Concrete Structures. This committee was charged with studying and reporting on the design and construction of precast concrete structures. One of this committee's goals was to prepare a draft of proposed design requirements for consideration by ACI Committee 318 for the ACI Building Code, Chapter 16. Changes were made in the fifth draft by ACI-ASCE Committee 550, prior to its submission to ACI Committee 318.

The PCI report presented in the following pages includes some of the changes suggested by ACI-ASCE 550, but it also was enlarged to include material not contained in the earlier drafts. It is being published as a guide and to generate comments from design professionals as well as from firms producing precast concrete.

PCI Technical Activities Committee

PART 1 — RECOMMENDATIONS

1 — Scope

1.1 — These provisions apply to precast concrete members, defined as members cast elsewhere than their final position in a structure.

1.2 — All provisions of the ACI Building Code[1] should apply to structures incorporating precast concrete members, except as specifically modified herein.

2 — General

2.1 — Design of precast members and connections should consider all loading and restraint conditions from manufacture to in-place use.

2.2 — When precast members are incorporated into a structural system the forces and deformations at connections, and from interconnected members, adjoining members and the structure should be considered. The design of precast members and connections should include all forces to be transferred, including initial and long term creep and shrinkage deformations and temperature effects.

2.3 — Precast members and connections should be designed to provide for manufacturing and erection tolerances.

2.4 — Prescriptive provisions of this report provide conservative minimums. However, where analysis or testing can demonstrate equivalent performance, it is not the intent of this report to preclude the use of other procedures.

3 — Precast Floor and Roof Systems

3.1 — Precast elements should be interconnected so as to maintain deformation compatibility with adjoining members.

3.2 — Load transfer between members should be based on tests or analyses.

3.2.1 — For solid or hollow-core slabs having a span-to-depth ratio of 10 or greater, concentrated point loads or line loads may be distributed between adjacent slab elements of similar depth. A concentrated load may be transferred by a keyway filled with grout or concrete, mechanical connectors, composite topping or a combination thereof. Load distribution should be uniform in the middle half of the slab along a line perpendicular to the span for a maximum width of $l/2$ when there are members on each side and $l/4$ when a member exists on one side only. Distribution width should be interpolated from a width of 4 ft (1.22 m) at the face of support to a maximum of $l/2$ at $l/4$ from the face of support when there are members on each side, and from a width of 1 ft (0.305 m) at the face of support to a maximum width of $l/4$ at $l/4$ from the face of support when a member exists on one side only.

3.2.2 — Transfer of loads should consider the effect of openings.

3.3 — Precast floor and roof elements used as a diaphragm should be interconnected so as to transfer total in-plane forces by grouted joints, structural topping, mechanical connectors or a combination thereof, provided interaction effects are considered.

3.3.1 — Mechanical connectors, when used, should not be spaced further apart than 8 ft (2.44 m) on centers. At least one connector should be placed between any adjacent elements.

3.3.2 — Total in-plane force should be determined by analysis but in no case should connectors be designed for a factored load less than 200 lb per linear ft (2920 N/m) acting in any direction.

3.3.3 — Diaphragms should be anchored to supporting members.

3.4 — Precast slabs not greater than 8 ft (2.44 m) wide, designed as one-way systems in which the flexural reinforcement is evenly distributed across the width of the member, need not contain temperature and shrinkage reinforcement required in Section 7.12 of the ACI Building Code[1] in the direction normal to flexural reinforcement.

3.4.1 — Where precast floor or roof elements are topped with a structural topping slab, temperature and shrinkage reinforcement should be provided in the transverse direction in accordance with Section 7.12, ACI Building Code,[1] based on the average net thickness of the topping slab.

4 — Precast Wall Systems

4.1 — Precast nonprestressed bearing and nonbearing walls should be designed in accordance with the provisions of Chapter 14, ACI Building Code,[1] except that the area of horizontal and vertical reinforcement in each direction should not be less than 0.001 times gross concrete area. Spacing of reinforcement should not exceed 30 in. (762 mm) for interior walls or 18 in. (457 mm) for exterior walls.

4.2 — When factored loads on wall members not greater than 8 ft (2.44 m) in width can be resisted by reinforcement in one direction only, and when such reinforcement is distributed over the width of the member in accordance with Section 7.6.5, ACI Building Code,[1] and Section 4.1 (above), minimum shrinkage and temperature reinforcement requirements of Section 7.12, ACI Building Code,[1] and the minimum reinforcement requirements of Section 4.1 (above) may be waived for the direction normal to the flexural reinforcement.

4.3 — Openings should be considered in the analysis of wall panels subject to in-plane and/or normal forces.

4.4 — Analysis for axial load transfer through joints between adjacent wall panels should consider behavior of the joint, stiffness of individual panels and the effect of load eccentricity.

4.5 — For precast concrete bearing wall structures three or more stories in height, forces between horizontal and vertical members, as well as perimeter forces in floor and roof diaphragms, should be determined from a structural analysis and appropriate reinforcement provided.

5 — Connections

5.1 — Precast elements may be designed to act either as independent elements or, when properly joined, as composite units. Where independent behavior is assumed, joints should be detailed to accommodate anticipated deformations. When precast units rely upon other elements to resist either in-plane or transverse loads, connections capable of transferring interactive forces should be provided.

5.1.1 — Interactive effects need not require elastic behavior of all connections. Ductility and damping characteristics established by tests may be used to determine connection design criteria and acceptability.

5.2 — Forces may be transferred between precast elements through grouted joints, structural topping, mechanical connectors or a combination thereof, provided interactive effects are considered. Load transfer between elements should be based on test data or analysis.

5.2.1 — Effect of differences in axial deformation between adjacent precast elements should be considered when analyzing load transfer.

5.2.2 — Post-tensioning may be used to transfer loads when it can be established that system behavior is equivalent to that provided when conventional connections are used.

5.3 — Analytical procedures developed in the ACI Building Code[1] may be used to establish the adequacy of elastic connections.

5.3.1 — Shear friction may be used to transfer loads between adjoining precast elements or between precast elements and cast-in-place concrete. An effective shear friction coefficient, μ_e, may be used in lieu of μ in Eq. (11-26), ACI Building Code,[1] where:

$$\mu_e = 1000\,\lambda A_c\,\mu / V_u$$

and

$$V_u = \phi V_n$$

Shear strength V_n should be limited as specified in Table 1 except that in no case should V_n exceed limits specified in Section 11.7.5, ACI Building Code.[1] Total shear transfer may include a combination of dissimilar joining conditions provided force displacement characteristics are considered.

Table 1. Shear friction coefficients.

Crack interface condition	Recommended μ	Maximum μ_e	Maximum V_n, lb
1. Concrete to concrete, cast monolithically	1.4λ	3.4	$0.30\lambda^2 f'_c A_{cr} \leq 1000\lambda^2 A_{cr}$
2. Concrete to hardened concrete with roughened surface	1.0λ	2.9	$0.25\lambda^2 f'_c A_{cr} \leq 1000\lambda^2 A_{cr}$
3. Concrete to concrete	0.6λ	2.2	$0.20\lambda^2 f'_c A_{cr} \leq 800\lambda^2 A_{cr}$
4. Concrete to steel	0.7λ	2.4	$0.20\lambda^2 f'_c A_{cr} \leq 800\lambda^2 A_{cr}$

5.3.2 — Concrete topping may be considered to transfer in-plane forces between precast elements in accordance with the following:

5.3.2.1 — When joints between precast members are filled with grout or concrete, overall net thickness of construction may be considered to resist in-plane forces.

5.3.2.2 — When joints between precast members are not filled, topping alone shall be designed to resist total in-plane forces.

5.3.2.3 — The capacity of mechanical connectors may be used in conjunction with the load transferred by the concrete.

5.4 — Precast floor and roof members not built integrally with supports (simply supported) should satisfy the following:

5.4.1 — Bearing at contact surfaces between supported and supporting member should not exceed bearing strength for all surfaces, including bearing pad. Concrete bearing strength should be as given in Section 10.15, ACI Building Code.[1]

5.4.2 — The distance from edge of support to end of precast member in direction of span should be detailed to be at least 1/180 of clear span, l, but not less than:

For solid or hollow-core members: 2 in. (51 mm) (nominal)

For beams or stemmed members: 3 in. (76 mm) (nominal)

The designer should consider volume changes and tolerances when establishing member lengths.

5.5 — When approved by the Engineer, items embedded in precast concrete components (such as dowels or inserts), that either protrude from concrete or remain exposed for inspection, may be embedded while the concrete is in a plastic state provided:

5.5.1 — Embedded items are not required to be hooked or tied to reinforcement within plastic concrete.

5.5.2 — Embedded items are maintained in correct position while concrete remains plastic.

5.5.3 — Embedded items are properly anchored to develop required factored loads.

6 — Identification and Marking

6.1 — Each precast member should be marked to indicate location and orientation in the structure and date of manufacture.

6.2 — Identification marks should correspond to placing plans.

6.3 — All details of reinforcement, connections, bearing seats, inserts, anchors, concrete cover, openings, lifting devices, and specified strength of concrete at stated ages or stages of construction should be shown on the shop drawings.

7 — Transportation, Storage and Erection

7.1 — During curing, stripping, storage, transportation and erection, precast members should not be damaged. A precast concrete member should not be rejected for reason of minor cracking or spalling where strength and durability are not affected.

7.2 — Precast members should be adequately supported and braced during erection to ensure proper alignment and structural integrity until permanent connections are completed.

8 — Strength Evaluation of Existing Precast Construction

8.1 — Provisions of Chapter 20, ACI Building Code,[1] should apply to precast concrete members except as modified in this section.

8.2 — Precast elements that are intended to respond to loads with cast-in-place concrete as a composite member may be tested as a precast element alone in accordance with the following:

8.2.1 — For precast prestressed elements, an equivalent load should be determined that will produce the same calculated extreme fiber stress in tension as would exist in the composite member if subjected to the loads required by Chapter 20, ACI Building Code.[1]

8.2.2 — For precast nonprestressed elements, an equivalent load should be determined that will produce the same calculated force in the tension reinforcement as would exist in the composite member if subjected to the loads required by Chapter 20, ACI Building Code.[1]

8.3 — Cracking should not constitute evidence of failure provided other criteria are met.

8.4 — Retest of precast prestressed members should be allowed. The criteria of Section 20, ACI Building Code,[1] should apply.

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PART 2 — COMMENTARY

Precast concrete is defined as concrete elements cast elsewhere than in their final position, which are then erected and connected in final position in the structure. The regular provisions of the ACI Building Code[1] for cast-in-place concrete apply except for the special provisions of this report.

Design and construction requirements for precast concrete structural elements differ in some respects from those for cast-in-place concrete structural members. Where provisions for cast-in-place concrete apply equally to precast concrete, they have not been repeated in this report. Similarly, items related to prestressed concrete in Chapter 18, ACI Building Code,[1] and composite concrete in Chapter 17, ACI Building Code,[1] that apply for precast concrete (or overrule similar sections given elsewhere in the ACI Building Code[1]) are not restated in this report.

More detailed recommendations concerning precast concrete are given in the following publications:

- *Industrialization in Concrete Building Construction.*[2] Reports on the design, production and assembly of precast and cast-in-place industrialized concrete construction. Assesses aspects of structural design and problems related to structural safety.
- *Precast Concrete: Handling and Erection,*[3] by J. J. Waddell. Reviews the advances made in the art of precasting in recent decades. Covers precasting methods and equipment, systems building concepts, types of precast units, on-site precasting, tilt-up and erection techniques.
- *PCI Manual on Design of Connections for Precast Prestressed Concrete.*[4] Presents basic understanding of connection behavior and recommends design procedures. Contains design aids and examples.
- *PCI Design Handbook — Precast and Prestressed Concrete,* Third Edition.[5] Provides load tables for common industry products and procedures for design and analysis of precast and prestressed elements and structures composed of these elements. Contains design aids and examples.
- *Plant Cast Precast and Prestressed Concrete – A Design Guide.*[18] by W. R. Phillips and D. A. Sheppard. Gives design process for many precast and precast, prestressed concrete products with step-by-step procedures and numerous examples.
- *Connections for Precast Prestressed Concrete Buildings — Including Earthquake Resistance*[7] by L. D. Martin and W. J. Korkosz. Updates available information on design of connections, evaluates over 100 connections typically used in the industry, and includes design aids and extensive references.

Code requirements related to aggregate size, concrete cover for reinforcement and splicing of reinforcement are provided in the ACI Building Code.[1]

There is no minimum size stated for columns as in earlier editions of the ACI Building Code. However, while fire performance ratings do not fall within the scope of the ACI Building Code, the designer is cautioned that the general building code must be consulted in this respect. With small members, consideration must be given to fire performance. The actual fire performance of a concrete member is a function of both the cover over the reinforcement and the relationship between the volume of a member and its exposed surface area. Similarly, when chemical and corrosive considerations are necessary, the designer must refer to available test data augmented by judgment.

The tolerances required by Section 7.5, ACI Building Code,[1] are considered as a minimum acceptable standard for reinforcement in precast concrete. The

Engineer should refer to publications of the Prestressed Concrete Institute (Refs. 5, 6, 8, 9 and 15) for guidance on standard industry tolerances.

1 — Scope

The provisions of this report relate to concrete members which are not cast in place. They apply to products, either prestressed or nonprestressed, that are cast in any location other than their final position in a structure.

2 — General

While the design for precast concrete is developed as for cast-in-place concrete (except as provided in Chapters 17 and 18, ACI Building Code[1]), special considerations are necessary for precast elements.

The stresses developed in precast elements during the period from casting to final connection may be greater than the actual service load stresses. Handling procedures may cause permanent deformations. Hence, special care must be given to the methods of storing, transporting and erecting precast elements.

It is also vitally important to consider the effects of connections and interconnected elements with respect to precast elements. The structural behavior of precast elements may differ substantially from that of similar members that are cast in place and are monolithic. Design of connections which transmit forces due to shrinkage, creep, temperature, elastic deformation, wind forces and earthquake forces requires particular care in precast construction. Details of such connections are especially important for adequate performance of precast construction.

Precast concrete construction affords a wide variety of applications. A prescriptive procedure that covers all applications is clearly impossible. Procedures which are representative of typical uses of precast concrete are contained herein to establish guidelines for the proper design of precast systems. In atypical cases these guidelines may not be appropriate or, if used, might even produce adverse effects. Then, the designer is encouraged to use accepted analytical procedures or test data to justify alternate means of satisfying the intent of the prescriptive provisions contained in this report.

The tolerances selected will affect design, particularly of connections. In order to prevent misunderstanding, such tolerances should be listed in the design. This may be done by reference to an accepted industry standard, such as those published by the Prestressed Concrete Institute,[8,9] or by specifically listing the tolerances.

Precast elements may be designed using either the strength design method of the ACI Building Code[1] or the alternate method of Appendix B, ACI Building Code.[1]

When the design of precast members and connections is assigned to the precast manufacturer, the Engineer should indicate any special requirements or functions that must be considered in the design.

3 — Precast Floor and Roof Systems

3.2.1 — Grout keys, mechanical connectors, or a composite topping will permit distribution of concentrated point and line loads. Such distribution is a function of the stiffness of the elements, the behavior of the connections, and the location of the load relative to other elements and to the support. The recommendations herein for solid or hollow-core slabs are considered to be conservative.

Load transfer between precast concrete members composed of stems and thin slabs are currently being studied in the hopes of establishing guidelines for the redistribution of vertical loads. Provisions for hollow-core and solid slabs do not apply.

3.4 — See Commentary Section 4.2.

3.4.1 — The nature of assembled precast units in precast concrete structures tends to relieve shrinkage stresses along joints which occur between units. This jointing also provides some thermal relief. When units are joined by a topping slab, shrinkage and thermal forces must be considered since the net section of the topping slab is the element which produces shrinkage and temperature associated strains. Reinforcement to counter these effects should be derived based on the net thickness of the generating component.

4 — Precast Wall Systems

4.1 — The provisions for lower minimum reinforcement and greater spacing of reinforcement in precast wall panels recognize that precast panels have very little restraint at their edges during early curing stages and will not build up stresses due to shrinkage of the same magnitude that a cast-in-place wall does due to restraint from the foundation and surrounding structural elements.

4.2 — For concrete elements, such as hollow-core slabs, solid slabs or slabs with closely spaced ribs, either conventionally reinforced or prestressed, used as bearing or nonbearing wall members, there is usually no need to provide transverse reinforcement to withstand stresses in the short direction. The width or short dimension of the element is limited to that which is practical to handle and ship, and thus is generally less than a dimension wherein shrinkage and temperature stresses can build up to a magnitude requiring control reinforcement. In addition, much of the initial shrinkage occurs before the elements are tied into the structure, and, once in the final structure, the elements are usually not as rigidly connected transversely as monolithic concrete. Thus, the transverse restraint stresses due to both shrinkage and temperature change are significantly reduced to the point where transverse control reinforcement is not required. This waiver is not permitted with a transverse dimension greater than 8 ft (2.44 m).

In elements such as single and double tees with thin flanges, and composite systems with thin slabs and steel ribs, flexural stresses in the transverse direction will usually require transverse reinforcement normal to principal reinforcement. If required, the amount of reinforcement should not be less than the minimum shrinkage and temperature reinforcement required by Section 7.12, ACI Building Code,[1] for floor and roof elements. For wall elements this limitation is overly conservative and should not be required.

4.5 — Bearing Wall Structures. A structural analysis is essential and should include the effects of volume changes and the forces induced by gravity loads and lateral loads. If the analysis requires reinforcement, the following minimum tie forces (see Fig. 1) are recommended:*

T_1 — A factored load of 1500 lbs per ft (21890 N/m) of wall support to provide a continuous load path in the direction of the span of floor or roof members and to tie floor and roof members to both interior and exterior bearing walls. The tie spacing should not exceed 8 ft (2.44 m).

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* These minimum tie forces, in precast concrete structures three or more stories in height, are recommended to ensure continuity and structural integrity. They are based on recommendations given in the PCI report[10] "Considerations for the Design of Precast Concrete Bearing Wall Buildings to Withstand Abnormal Loads," which was prepared by the PCI Committee on Precast Concrete Bearing Wall Buildings. Abnormal loads are defined[20] as those having a low probability of occurrence, such as from high explosive detonation, service system explosion, serious construction error, accidental exterior impact, fire, flood or tornado.

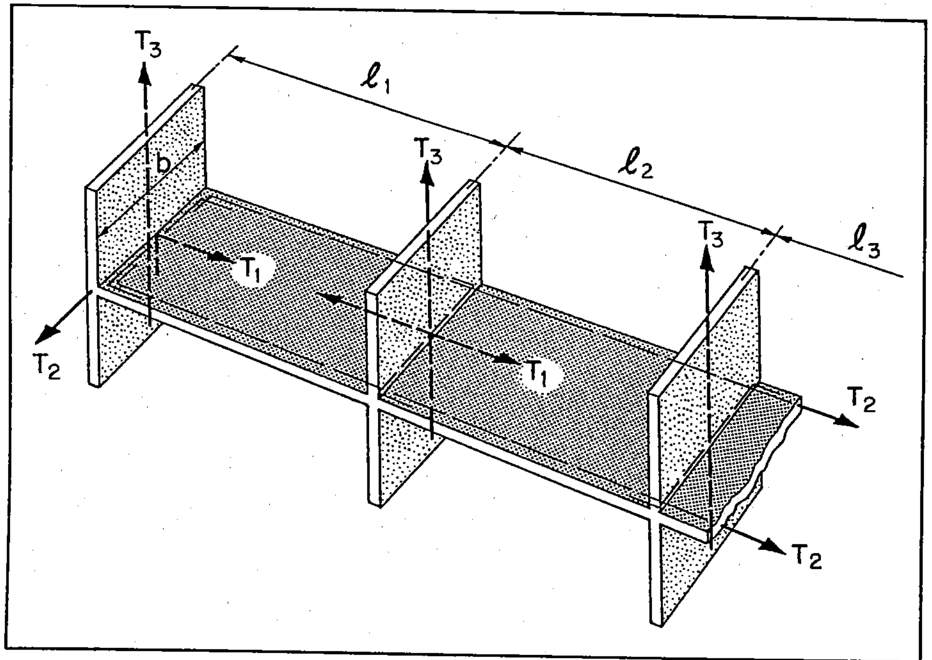

Fig. 1. Recommended tie forces in precast concrete bearing wall buildings.

T_2 — A factored load of 16,000 lbs (71170 N) to provide a continuous perimeter tie at each floor and roof level. This reinforcement may be located in the floors or roof or in the walls and should be located as close to the perimeter as practical, but not farther than 4 ft (1.22 m) from the edge of the structure or within 4 ft (1.22 m) of the floors or roof when reinforcement is located in the walls (see Fig. 2).

T_3 — A factored load of 3000 lbs per horizontal ft (43780 N/m) of wall to provide vertical ties in the bearing wall panels.

Tie reinforcement may be provided using unstressed prestressing steel, wire, deformed bars or mechanical connectors of the appropriate size. To ensure ductility, the nominal strength of the ties should be based on yield stress. The capacity and bond length for unstressed prestressing steel should develop the yield stress of the tie.

5 — Connections

Precast concrete can be used in many ways in a building system and as a result be subjected to a variety of loads. When a precast concrete unit acts in conjunction with either another precast concrete unit or cast-in-place concrete, the connection is usually the weakest link. Connections are always subjected to thermal and shrinkage strains which are disproportionate to their size; said another way, thermal, creep and shrinkage strains which occur in precast elements often must be absorbed in the connections. If a connection cannot tolerate these strains it cannot be relied upon to transfer design loads. Prescriptive requirements which form an essential safety net in basic building codes do not lend themselves to connection design for precast structures and hence it is the intent of this section to allow the design engineer the flexibility necessary to select the connection philosophy appropriate for the project being considered. It is essential that the engineer focus on the load path and insure that connections satisfy conditions of equilibrium and compatibility. Compatibility considerations must of course consider the viscoelastic nature of concrete.

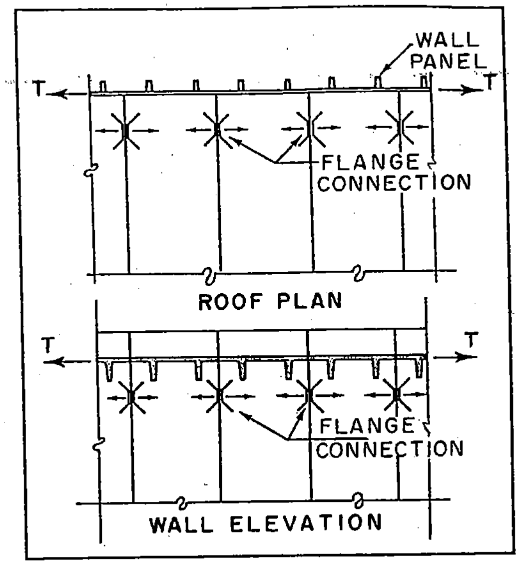

Fig. 2. Chord forces in precast wall panel system.

When precast loads are subjected to earthquake induced displacements the designer is cautioned that an elastic response based on subyield-level loads does not correctly predict structural loads or movements.

5.1.1 — An elastic design criterion for connections is often inappropriate. The ability of a connection to yield and still transfer design loads is a desirable characteristic, thus, post yield connection characteristics should be understood. Post yield behavioral characteristics of connections can be used in the earthquake design of precast concrete buildings.[12] Connections which exhibit good post yield behavioral characteristics should be used wherever possible.

5.2 — Connection possibilities in precast concrete are numerous but are usually constrained by construction procedures. Construction stability and final design considerations require diverse connection techniques and quite often the combination of various connection types. Connection test programs, though extensive, seldom duplicate the ideal connection for a project. As a consequence it is important that the designer be permitted to extrapolate and combine test data to analytically justify connection designs.

Solid or hollow-core elements are generally assembled with space between for field placed grout. It is generally impractical to extend reinforcement or dowels from the sides, thus the shear transfer depends on the roughness of the sides and the strength of shear keys, if any.

The nominal shear force (in pounds) on grout joints should not exceed the following:

1. For smooth surfaces .... $40\,d_g l$
2. For roughened surfaces .... $80\,d_g l$

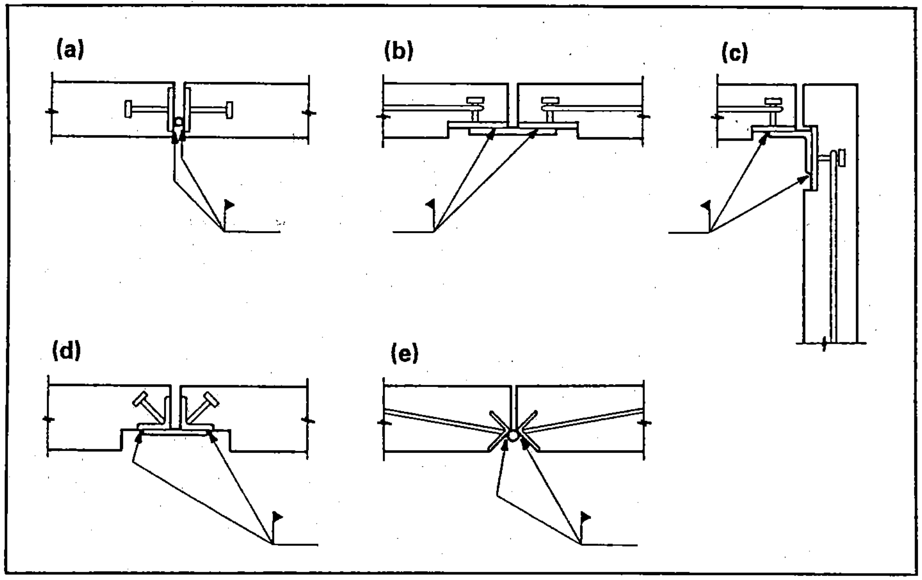

Fig. 3. Welded alignment connections for wall panel components.

where

d_g = height of grout joint, in.
l = length of grout joint, in.

Note that a keyway cast into the side of a joint is considered a roughened surface.

When mechanical connectors are used, the shear forces should be properly transferred between each element of the connection. Anchorage of the connectors may be analyzed using shear friction, or may be based on test results. When joints are interrupted by openings, the area remaining should be sufficient to transfer the calculated forces.

When connecting media with differing structural properties act across a joint, their relative stiffnesses, strengths and ductilities must be accounted for if their combined behavior under the anticipated joint loads and deformations is to be predicted accurately.

For example, imagine two wooden blocks tied together with a piece of thread and a rubber band. Initial strength and stiffness of the connection are determined by the thread; adding two or three more rubber bands will have no effect. If the anticipated loading requires the combined ultimate strengths of one strand of thread plus one rubber band, the connection is inadequate as described; the thread will fail before the rubber band stretches far enough to develop any force.

Grouted shear keys are stiff and brittle. Mechanical connectors tend to be ductile. Their counterparts in the above example are obvious.

5.2.1 — Differential axial movement can be caused by shrinkage, prestressing forces or thermal effects. If not adequately allowed for in connection design, the consequences can be serious. A wall panel connection similar to the one shown in Fig. 3(a) cannot tolerate the differential temperature induced strains which will occur between floor slabs and wall panel. Providing a connector which permits some longitudinal movement [see Fig. 3(d)] in the connector could permit thermal strains to occur without affecting their in-plane load carrying capability. Bolted connectors with slotted plates should be used wherever possible.

5.2.2 — Large panel precast structures are used throughout the world to develop residential buildings. Recently, tests have been conducted to evaluate the performance of precast panels utilizing post-tensioning[13] as a primary connection. These tests indicate the superior performance of these types of connections.

5.3 — All connection designs need not be based on test data. Where analysis procedures developed in the ACI Building Code[1] are appropriate, they may be used. The subsections which follow deal with specific interpretations of provisions in the ACI Building Code.[1]

5.3.1 — The application of shear friction theory as it applies to precast concrete warrants modification. The modification proposed is discussed in detail in the PCI Design Handbook.[5] These recommendations are based on the work performed by Shaikh.[16]

5.3.2 — Composite diaphragms consisting of a precast element and a cast-in-place topping slab are a common means of transferring in-plane shear forces. Joints between precast elements represent a plane of inherent weakness much like any shrinkage crack in concrete. In fact, a shrinkage crack normally will occur directly over a joint between precast elements. Shear friction theory and the supporting test data were developed to establish a load transfer mechanism. The shear friction mechanism requires the formation of a truss mechanism where the concrete transfers the compression component while the steel absorbs tensile stresses. Allowable stresses are based on the effective areas of concrete and steel. When the joint is grouted so as to permit the transfer of compressive stresses it is reasonable to use this grouted area as a part of the gross area for load transfer purposes.

5.4.1 — The interface between precast concrete elements has been the subject of considerable research. Deteriorating bearing pads and spalling of concrete surfaces have dictated new design minimums. Bearing pad design must consider that the effects of permanent dead load are as important as ultimate

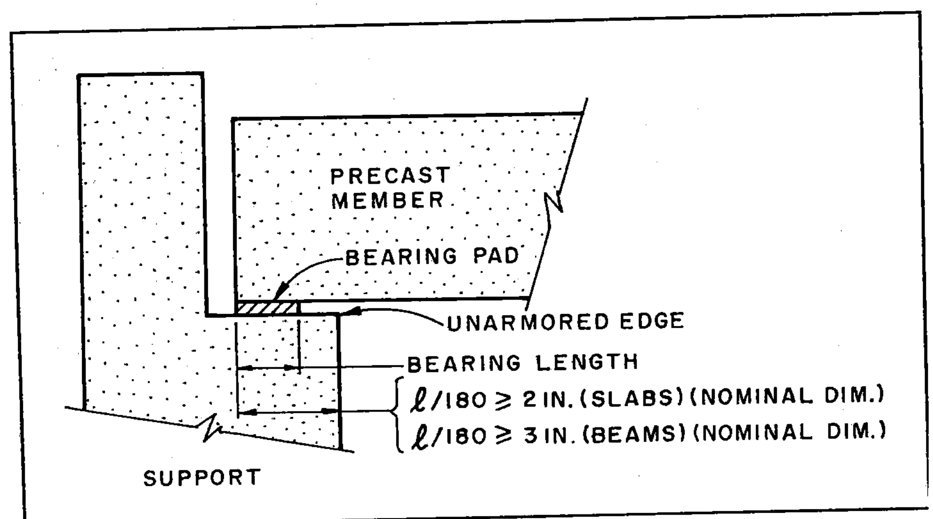

Fig. 4. Bearing length versus length of member on support.

load considerations. Design of bearing pads is discussed in Ref. 14. Chamfered edges are recommended on all bearing surfaces where members may rotate. Minimum seating depths must consider long term shrinkage and creep effects, temperature induced movements as well as tolerances. To prevent spalling under heavily loaded members, bearing pads should not extend to the edge of the support unless the edge is armored (see Fig. 4).

5.4.2 — Occasionally, precast members are used for spans in excess of 90 ft (27.45 m). For these long span units, a minimum distance from end of member to the edge of support greater than 6 in. (152 mm) may not be practical or required.

5.5 — Section 5.5 is an exception to the provisions of Section 7.5.1, ACI Building Code.[1] Many precast products are manufactured in such a way that it is difficult, if not impossible, to position reinforcement which protrudes from the concrete before the concrete is placed. Experience has shown that such items as ties for horizontal shear and inserts can be placed while the concrete is plastic if proper precautions are taken. Before giving approval, the Engineer should be satisfied that the detailing and workmanship will result in properly placed and anchored embedded items and that the concrete will be properly compacted around the items. This exception is not applicable to reinforcement which must be hooked or tied to embedded reinforcement or to fully embedded reinforcement.

7 — Transportation, Storage, and Erection

It is important that all temporary erection connections, bracing and shoring be clearly identified, as well as the removal sequence of these items. Guidance on assessing cracks in precast members is given in two PCI committee reports on fabrication and shipment cracks.[11,17]

8 — Strength Evaluation of Existing Precast Construction

Precast elements already in place in a structure are to be tested in accordance with the provisions contained in Chapter 20, ACI Building Code.[1]

When the strength of a precast member is questioned before it is incorporated in the structure, procedures for verifying member strength are different than those contained in Chapter 20. The provisions of Chapter 20 are modified in this section to provide a criterion for testing precast members before they are placed in the structure. The objective is to develop a test for the precast member which produces a level of tensile stress in the precast member equivalent to that which would be required under the provisions of Chapter 20 had the precast member already been incorporated in the structure and presumably able to benefit from the composite strength afforded by cast-in-place concrete.

* * *

NOTE: Discussion of this report is invited. Please submit your comments to PCI Headquarters by July 1, 1987.

REFERENCES

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