MASONRY PREFABRICATION

IN

SOUTHERN CALIFORNIA, USA

by

Walter L. Dickey
Consulting Structural Engineer.*

ABSTRACT

Discusses general development in Southern California of prefab masonry, the code design requirements for prefab in seismic areas, the testing of connections, and an outstanding example to illustrate benefits of prefabrication

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INTRODUCTION

This discussion is primarily limited to Southern California because the total overall subject of prefabrication is too large an item. Also, because detailed techniques and methods are limited to specific locale just as dialects are different for different areas, e.g., "English" as it is spoken in London, or in Scotland, or in USA or in Australia, although I understand it is the same language.

Although the local development in detail may be limited to restricted areas it is definitely influenced by other more or less distant local history, studies, development, improvement, and modulation (or accent.). Local personalities are frequently most influential factors.

The prefab method has long had a certain continuing charm and attraction, both aesthetically and economically, especially with regard to new improved methods and equipment,as available. It has the prestige connotation of "NEW", "mystical prefab", "high quality", "innovation",as well as attractive practical economy.

The above factors have led to at least one very attractive, unique, and unusual masonry prefab project, an example of the above benefits.

The following discussion is in the general outline of a look at HISTORY, ADVANTAGES, DESIGN REQUIREMENTS, BOLTS AND INSERTS, unique EXAMPLE, leading to CONCLUSION.

HISTORICAL

Masonry prefabrication has been seen sporadically in the East, e.g., large residential brick walled homes and warehouse walls in Ohio.

In the Midwest, i.e., Arizona, there was a machine prefabrication. Tomax was a method of providing prefabricated concrete block wall panels by machine prefabrication. This also was initiated in some other areas but did not receive widespread usage.

This machine laid prefabricated concrete block wall method was quite successful there. It automatically placed mortar bed joints, laid the block in a programed sequence, in a frame, placed them on the mortar bed joint and poured the head joints for course after course until completed and then moved the panel to storage. The machine was then franchised to several areas but the right specific enthusiastic personalities were not widespread enough for wide acceptance. In the San Francisco area it was effective for several items such as freeway sound barrier walls and warehouse walls.

There was a surge in prefab production in Denver, five contractors specializing in prefab. One survived by the expedient of franchising.

Then there was considerable prefab in Utah.

One of the most successful and recent blossoming of prefab was in the Northwest area of the USA. Three important phenomena occurred. One was that a good engineer skilled in masonry was an enthusiastic participant. Another item was that a well qualified masonry contractor set up a plant and specialized in prefab. Another was that a brick manufacturer was willing to promote and back the scheme with seminars, brochures and A/V presentations. There were several successful projects that demonstrated and proved the feasibility of prefab.

In Southern California there had been some excellent experiences with architectural precast concrete facing panels in a very successful manufacturing program, especially by Wailes Precast Concrete. This firm even included several precast panel projects with ceramic or terra cotta facings. Other Southern California precasters followed that lead with many very successful precast installations.

A recent prefab activity was the use of steel framed panels faced with Gail Plate, a ceramic tile facing.

The Masonry Institute of America, based in Southern California, recognized the feasibility of masonry prefab and provided many seminars showing methods, successful projects from other areas, and presented advantages of prefab.

ADVANTAGES

The principle of masonry prefabrication has been simmering, even boiling, for so long because of the many potential advantages for specific suitable projects. These advantages might be reviewed briefly in summary form as follows:

* Shortened, or telescoped, construction time for building enclosure.

* Less interference with other building trades as with scaffolding etc., for faster, more economical, job progress.

* More economical laying of panels under shop conditions.

* More assurance of good quality control.

* Greater flexibility in design.

* Greater freedom of dramatic shape and patterns.

* Provides the inherent benefits of masonry cladding, e.g.;

  Durability
  Low maintenance
  Brick character
  Solar energy conservation
  Fire endurance

* Quick economic provision of enclosure construction.

DESIGN PROVISIONS

The designs in Southern California have been under the jurisdiction of the Uniform Building Code of the International Conference of Building Officials. The

early design of cladding had been rather simple, merely design under simple conventional methods. However, after the Alaskan earthquake and the San Fernando quake of 1971, in which there were disastrous failures of many precast concrete panels, there was an almost hysterical reaction and quite conservative provisions were introduced into the Uniform Building Code by the Structural Engineers Association of Southern California. This is probably warranted because panels might pose a hazard to human life, because panel installations are so frequently above public areas and ways.

These code provisions are indicated in the following excerpts from the UBC.

(g) **Lateral Force on Elements of Structures and Nonstructural Components.** Parts or portions of structures, nonstructural components and their anchorage to the main structural system shall be designed for lateral forces in accordance with the following formula:

Magnitude, forces, depending on Zone.

$$F_p = ZIC_pW_p \quad \ldots\ldots (12\text{-}8)$$

The values of C_p are set forth in Table No. 23-J. The value of the I coefficient shall be the value used for the building.

EXCEPTIONS: 1. The value of I for panel connectors shall be as given in Section 2312 (j) 3 C.

The distribution of these forces shall be according to the gravity loads pertaining thereto.

For applicable forces on diaphragms and connections for exterior panels, refer to Sections 2312 (j) 2 C and 2312 (j) 3 C.

(h) **Drift and Building Separations.** Lateral deflections or drift of a story relative to its adjacent stories shall not exceed 0.005 times the story height unless it can be demonstrated that greater drift can be tolerated.

All portions of structures shall be designed and constructed to act as an integral unit in resisting horizontal forces unless separated structurally by a distance sufficient to avoid contact under deflection from seismic action or wind forces.

Provide for drift by strength to resist, or by permitting free motion.

B. **Reinforced masonry or concrete.** All elements within structures located in Seismic Zones No. 2, No. 3 and No. 4 which are of masonry or concrete shall be reinforced so as to qualify as reinforced masonry or concrete under the provisions of Chapters 24 and 26. Principal reinforcement in masonry shall be spaced 2 feet maximum on center in buildings using a moment-resisting space frame.

Arbitrary reinforcing required, to provide ductility in masonry.

C. **Exterior elements.** Precast or prefabricated nonbearing, nonshear wall panels or similar elements which are attached to or enclose the exterior shall be designed to resist the forces determined from Formula (12-8) and shall accommodate movements of the structure resulting from lateral forces or temperature changes. The concrete panels or other similar elements shall be supported by means of cast-in-place concrete or mechanical connections and fasteners in accordance with the following provisions:

Magnitude of building motion to provide for.

Connections and panel joints shall allow for a relative movement between stories of not less than two times story drift caused by wind or ($3.0/K$) times the calculated elastic story displacement caused by required seismic forces, or ½ inch, whichever is greater. Connections to permit movement in the plane of the panel for story drift shall be properly designed sliding connections using slotted or oversized holes or may be connections which permit movement by bending of steel or other connections providing equivalent sliding and ductility capacity.

Connection body to be ductile, and Design body for 4/3 force of (12-8).

Bodies of connectors shall have sufficient ductility and rotation capacity so as to preclude fracture of the concrete or brittle failures at or near welds.

The body of the connector shall be designed for one and one-third times the force determined by Formula (12-8). Fasteners attaching the connector to the panel or the structure such as bolts, inserts, welds, dowels, etc., shall be designed to ensure ductile behavior of the connector or shall be designed for four times the load determined from Formula (12-8).

Fasteners for 4 X force of (12-8)

Fasteners embedded in concrete shall be attached to or hooked around reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

The value of the coefficient I shall be 1.0 for the entire connector assembly in Formula (12-8).

BOLT AND INSERT CONNECTIONS

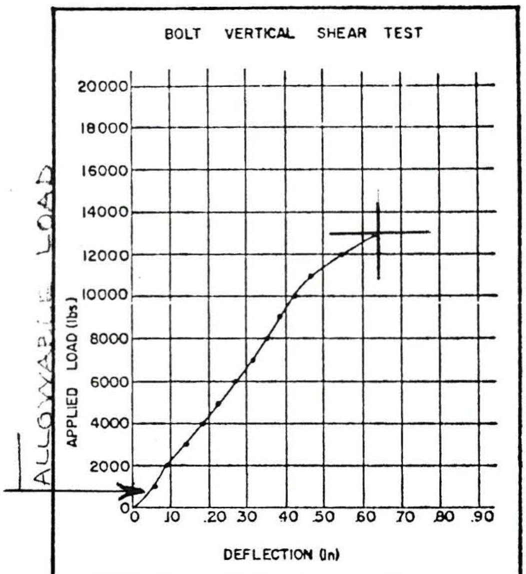
Early bolt allowable values under the UBC have been as shown in the following table for years.

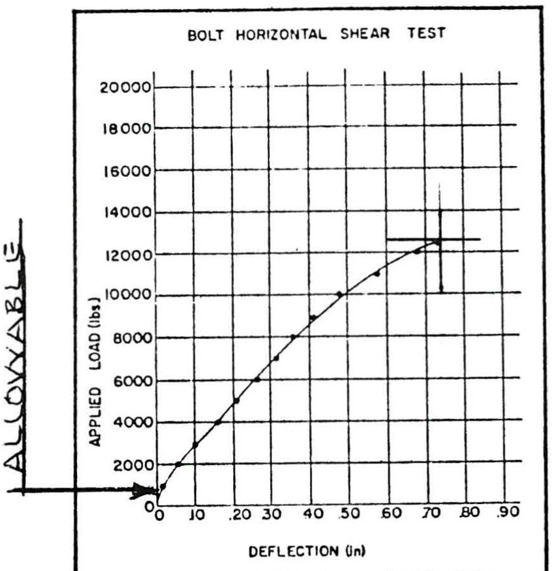
TABLE NO. 24-G—ALLOWABLE SHEAR ON BOLTS FOR ALL MASONRY EXCEPT UNBURNED CLAY UNITS

DIAMETER OF BOLT (Inches)	EMBEDMENT[1] (Inches)	SOLID MASONRY (Shear in Pounds)	GROUTED MASONRY (Shear in Pounds)
1/2	4	350	550
5/8	4	500	750
3/4	5	750	1100
7/8	6	1000	1500
1	7	1250	1850[2]
1 1/8	8	1500	2250[2]

[1]An additional 2 inches of embedment shall be provided for anchor bolts located in the top of columns for buildings located in Seismic Zones Nos. 2, 3 and 4.
[2]Permitted only with not less than 2500 pounds per square inch units.

These are traditional values as allowed for either uninspected or inspected or low strength or high strength masonry. Those values are really quite ineffectual provisions based on high factors of safety, for safe use in low strength masonry, with no edge distance requirements, no limits on location relative to joints, no values for pull-out or tension, i.e., not very precise valid limits. Western States Clay Products Association conducted tests for bolt shear values in high strength grouted hollow unit masonry obtaining good values. The allowable values permitted are marked on the curves of performance determined by the tests as can be seen, the allowable values were extremely conservative compared to the actual final ultimate capacity.



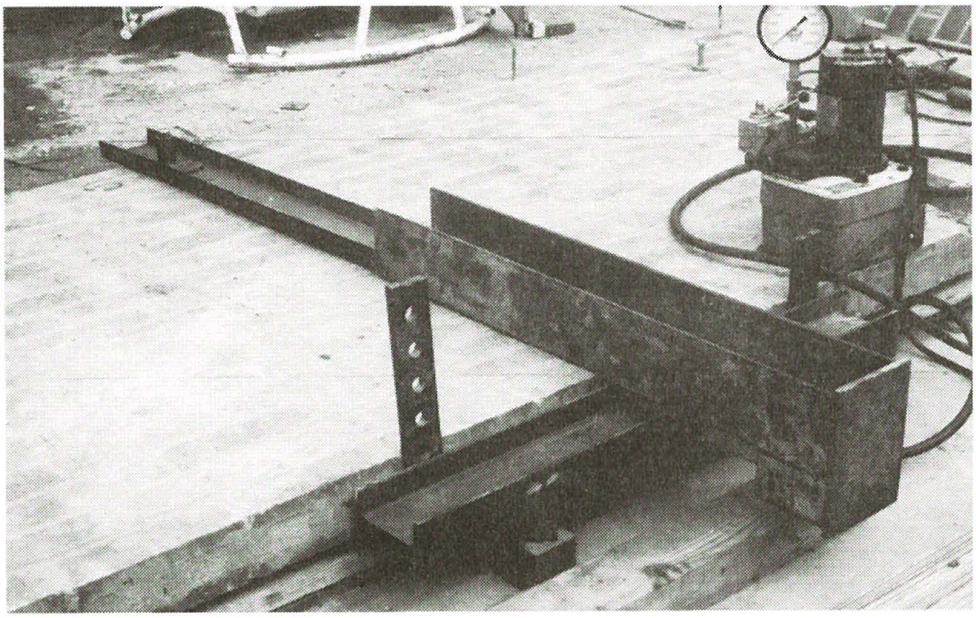


These are two of the load deflection curves obtained in testing the bolts in the Western States Clay Products Association program. They carried loads far in excess of the "Allowable" limit imposed by the 1/16" slip.

Obviously, additional testing was necessary for reasonable values of bolts in shear, as well as bolts in tension, for reasonable panel installations.

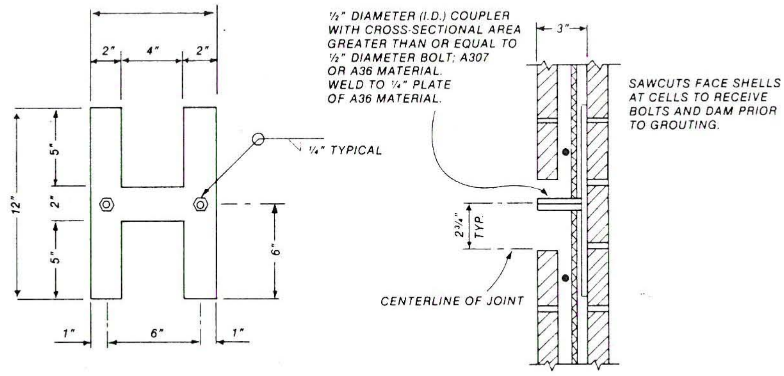
An initial pilot test program was made by Higgins Brick Company which showed quite high values to be possible. However, it was apparent that for the major load points of prefabricated panels that greater capacities would be needed for reasonable installations.

Although calculations could be made of various installations they would be rather complex and uncertain. Therefore, an extensive test program was performed by Higgins and R & R Masonry, trying several types of inserts.



The most successful types were then thoroughly tested in an extensive program at the University of California at Los Angeles (UCLA) to provide assured allowable capacities for shear vertically and horizontally as well as the otherwise indeterminate pull-out capacities.

The inserts tested at UCLA were as shown in the following drawing Figure of the two bolt insert. The four bolt insert was similar and was for the basic two point support of the loads.



DETAIL - TWO-BOLT ANCHORAGE INSERT — SECTION - TWO-BOLT ANCHORAGE INSERT

PATENT PENDING

Figure 2

These were to provide resistance to shear and also resist pull-out or push in failure shown in Figure

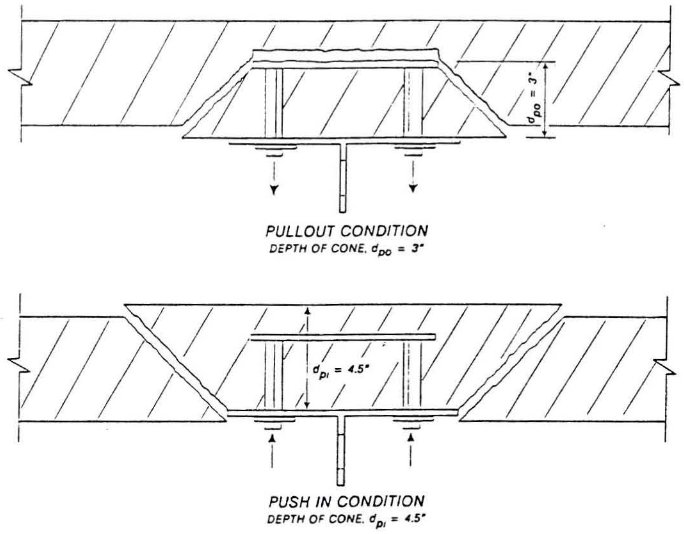


FIGURE 3 PULLOUT VS. PUSH-IN CONE FAILURES

These were tested for the specific loadings that would be imposed on a typical panel as shown in Figure 4 and the section Figure 5

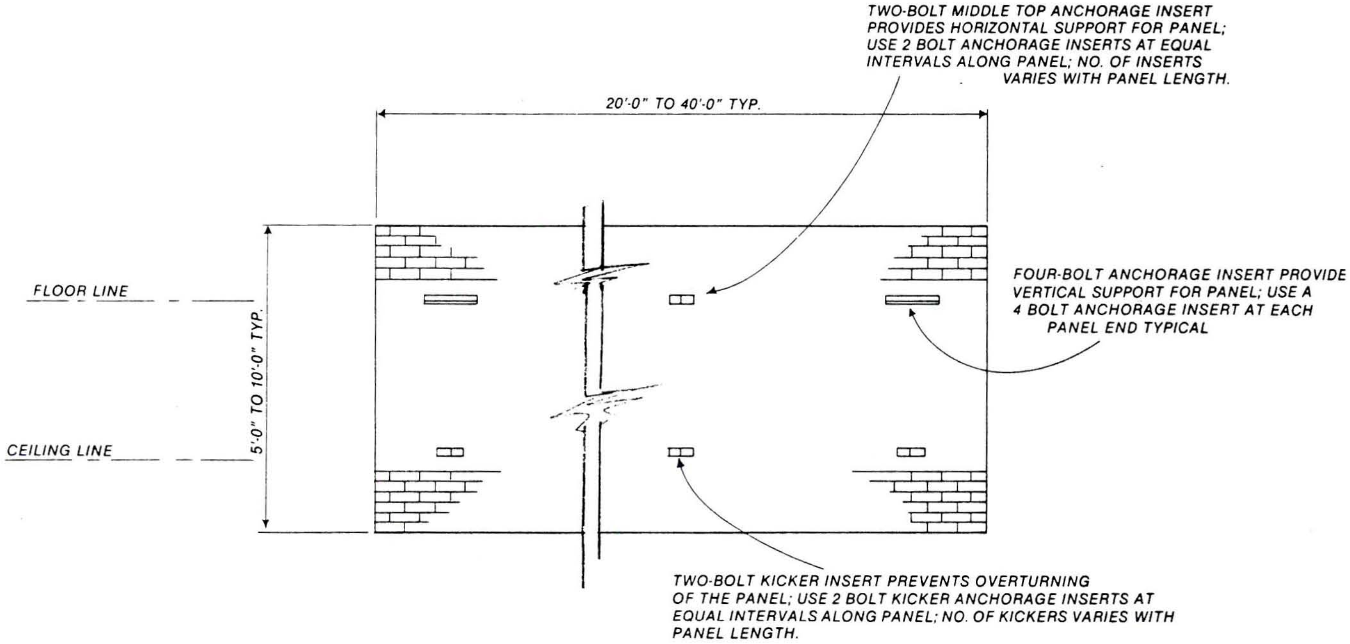
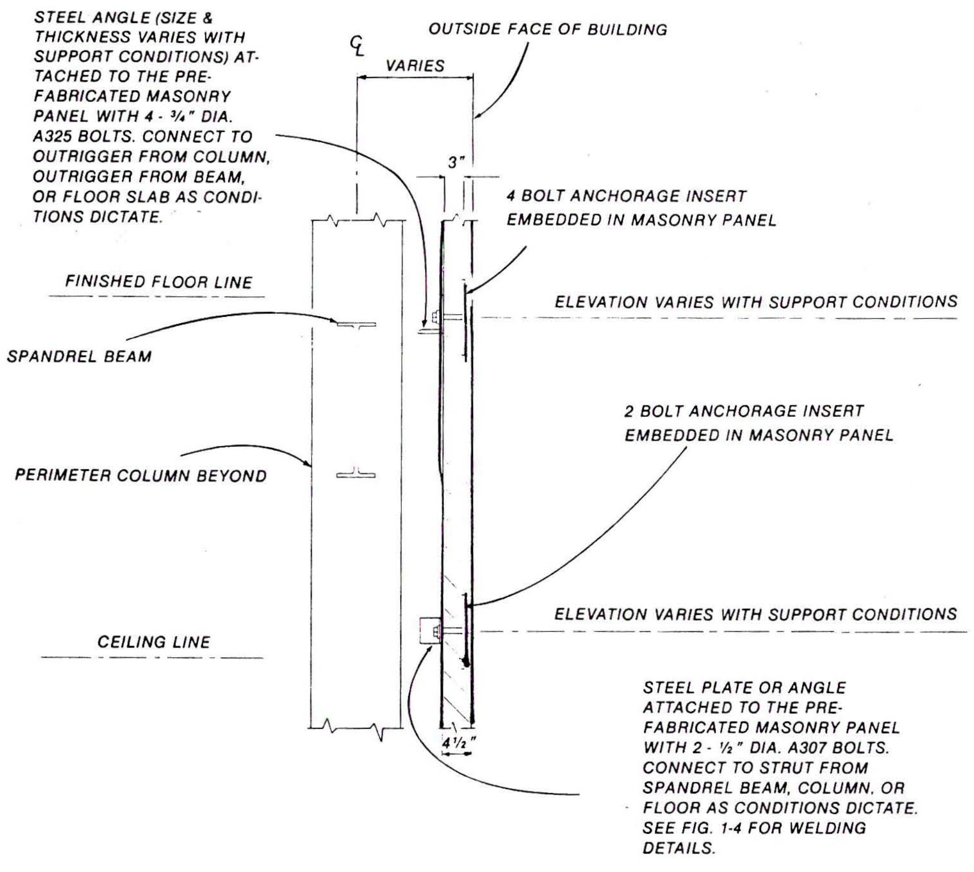


FIGURE 4 INSIDE ELEVATION – TYPICAL PREFABRICATED MASONRY PANEL



TYPICAL SECTION @ POINTS OF VERTICAL SUPPORT

NOTES:
1) CONNECTIONS OF STRUCTURAL STEEL AND MISCELLANEOUS IRON ELEMENTS NOT SHOWN FOR CLARITY.
2) DETAILS FOR ATTACHMENT OF THE PREFABRICATED MASONRY PANELS TO A REINFORCED CONCRETE FRAME ARE SIMILAR.

FIGURE 5 VERTICAL SECTIONS - CONNECTION DETAILS

The panel free body diagram of loadings anticipated was as shown in Figure 6

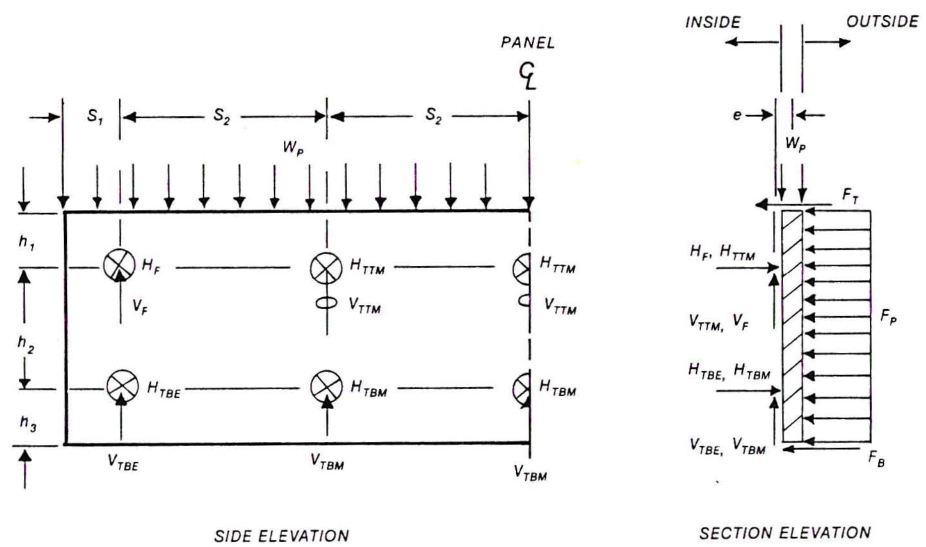


FIGURE 6 PANEL FREE BODY DIAGRAMS

The inserts were tested in a manner very similar to the Standard ASTM methods but with additional consideration of combined loading, e.g., the pull-out load test was made with some shear load applied, simulating field conditions.

The performance of the inserts under load to failure is shown in the load deflection curves. The pull-out Allowable Load was taken as 1/4 x ultimate load. The shear Allowable Load was also at 1/4 times the ultimate load and it agreed closely with the customary consideration of 1/16" slip as Allowable or limiting. The conventional code masonry bolt value capacity is plotted on these figures to illustrate the great increase that may be developed and the tremendous actual factor of safety that is provided, not only large but also ductile in nature.

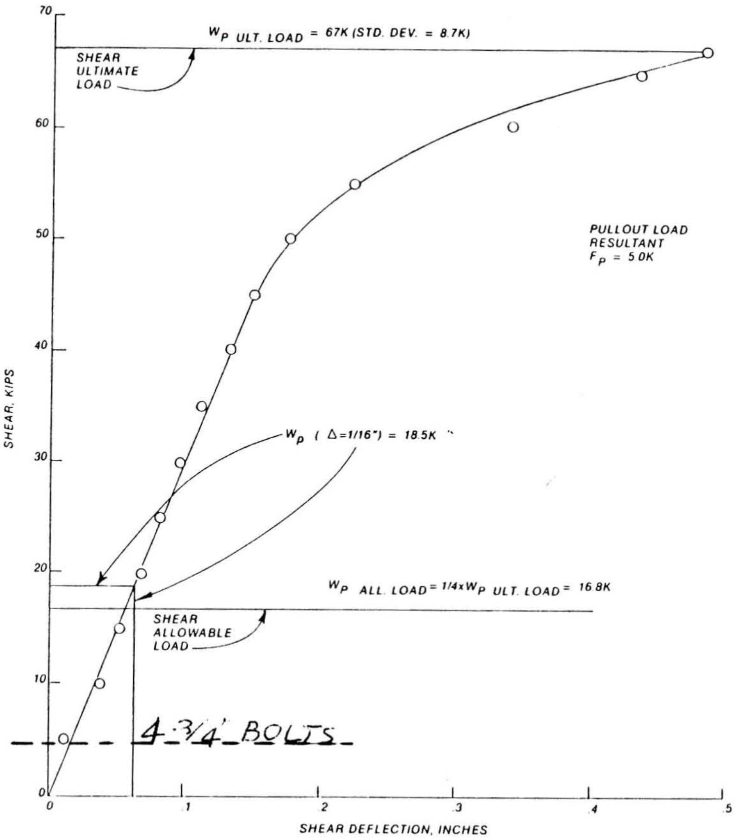


FIGURE 7 SHEAR LOAD-DEFLECTION RELATION: FOUR-BOLT ANCHORAGE INSERT FULL HEIGHT PROTOTYPE PANEL

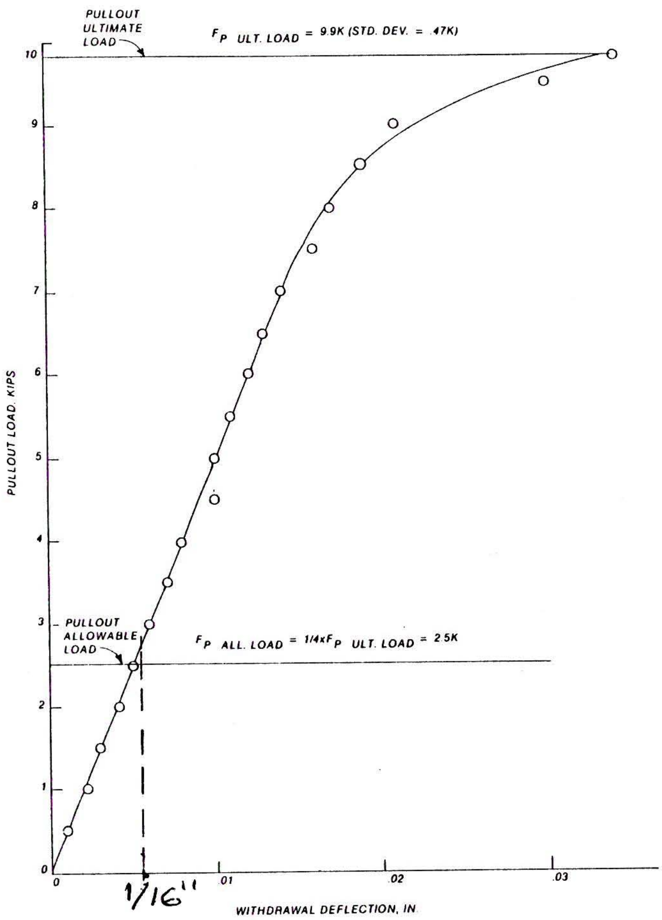
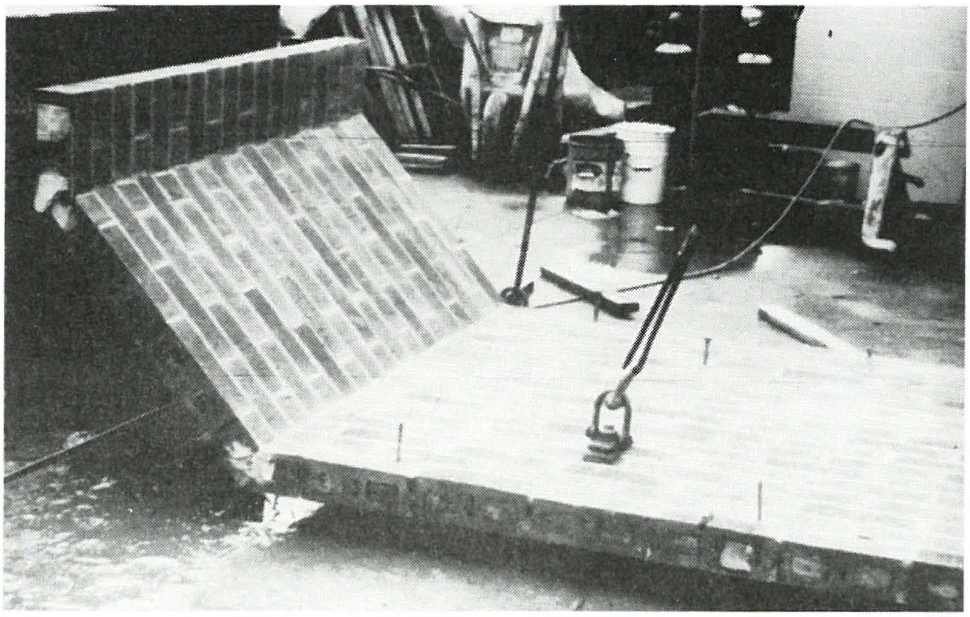


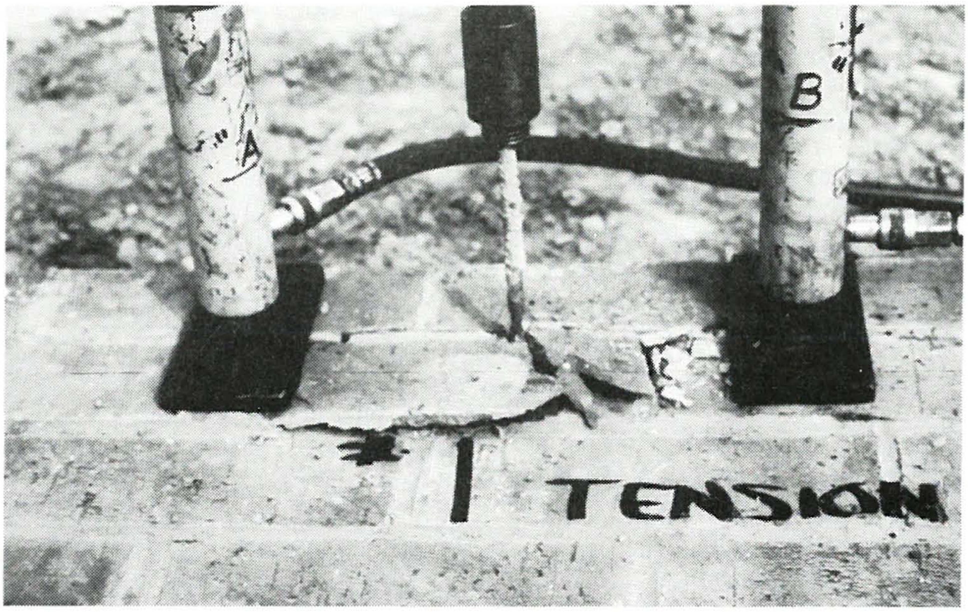
FIGURE 8 PULLOUT LOAD VS. WITHDRAWAL: TWO-BOLT MIDDLE TOP ANCHORAGE INSERT FULL HEIGHT PROTOTYPE PANEL

The most recent and best example of application of the prefab masonry is the $60 million office complex at 801 Civic Center in Santa Ana, California. The panels were fabricated at a site adjacent to the building. They were being constructed before the steel building frame was erected. The 4-story brick enclosure was then installed in less than two weeks, without interfering with other simultaneous construction stages.

An unusual feature of the panels is the inclusion of architectural precast concrete in portions of the panels.

The cost of fabricating the brick wall panels was much less than if they had been built in place, partly because of the extensive scaffolding that would be necessary.




B
A
TENSION

CONCLU$ION

"PRECAST" concrete has gone through the phases of "Innovation" and "Fad" to efficient construction methods. Now PREFAB masonry has gone through many false starts in many parts of the world until now it can be accepted as a viable construction method, providing:

Speed of construction schedules
Ease of construction methods
Assurance of quality control
Benefits of durable masonry cladding
Energy conservation
Reduced building weight
Less building waste space
Greater freedom of shape design
Ease of aesthetic variation in patterns

As shown in the example.