CHAPTER I
INTRODUCTION

1.1 Problem Statement

Precast concrete structures have the advantages of high quality control, and construction speed. The inadequate seismic response of pre-cast structures, which is mostly related to the connections, is a major concern and the subject of research efforts in many countries. The use of the pre-cast concrete structures in seismic areas necessitates the development of proper connectors between the pre-cast members, particularly in the column-footing connection. Such connection must exhibit sufficient strength, ductility, and energy dissipation capacity in order to serve its intended purpose. Previous studies dealing with pre-cast concrete components for use with mechanical splices are scarce. Mechanical splices are cost-effective devices that are commonly attached to structural members subjected to gravity loads. The use of couplers is prevalent mainly in non-seismic regions.

This research focuses on mechanical splices for application at the critical connections of pre-cast concrete columns in order to produce energy dissipation of structures. The failure is expected to occur in the splices rather than the reinforcement after the occurrence of strong ground shaking. In this way, structural repair can be carried out by replacing the new couplers. Figure 1.1 shows the threaded mechanical splices used in this study. Figure 1.2 depicts the mechanical splice in a precast concrete column.

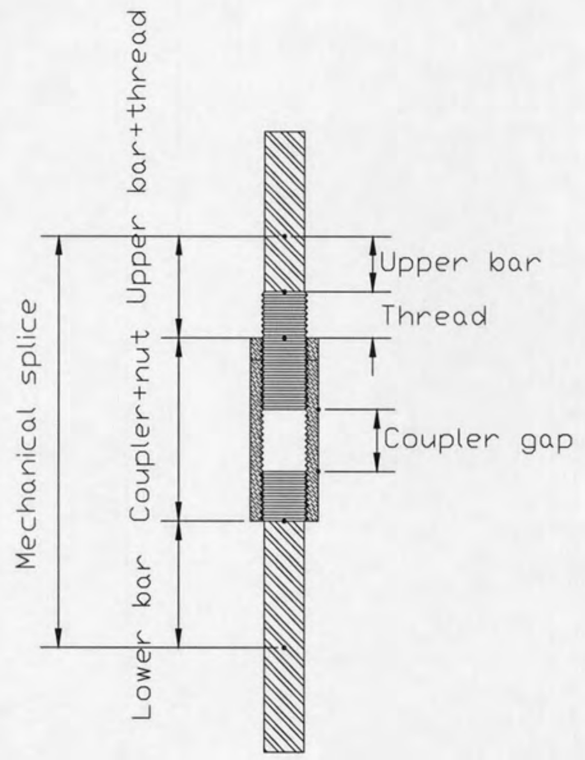


Figure 1.1 Threaded mechanical splice used in the study

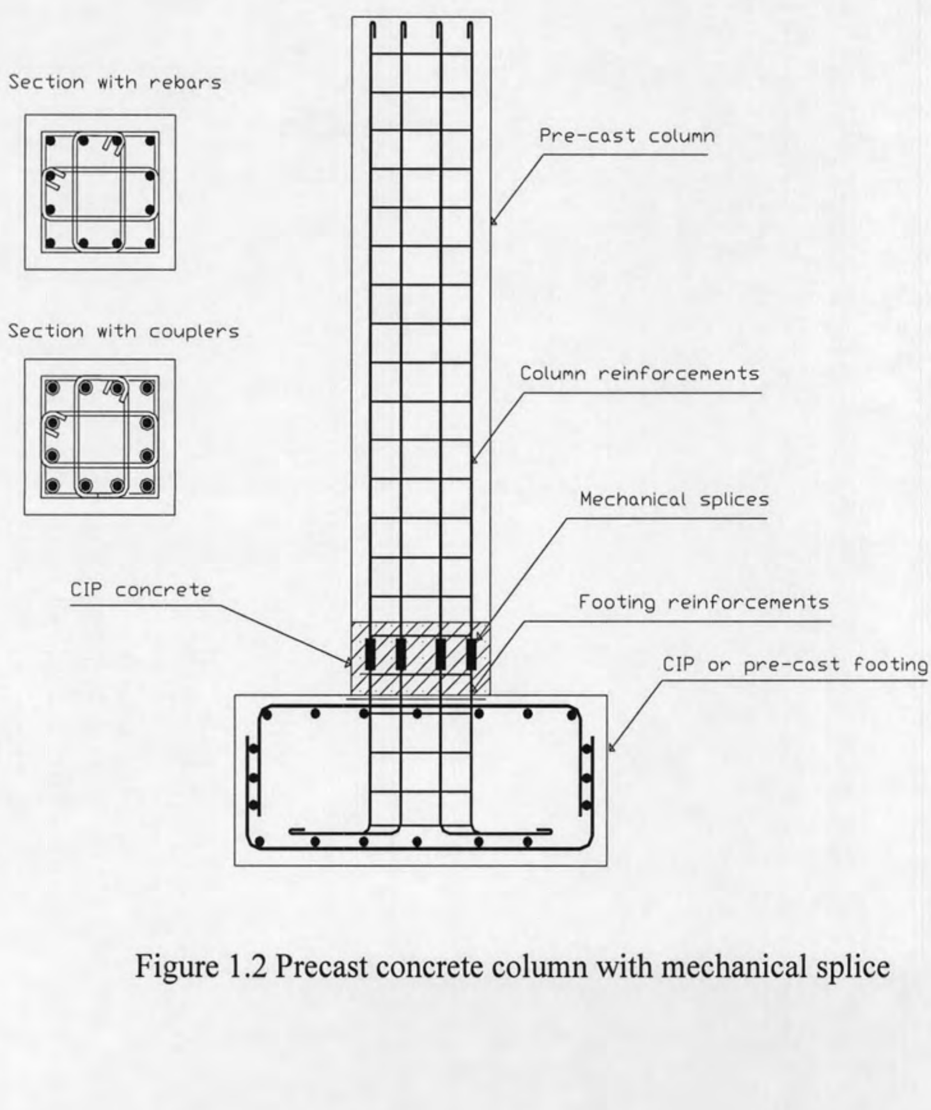


Figure 1.2 Precast concrete column with mechanical splice

1.2 Research Objectives

This research has the following specific objectives:

1. To develop threaded mechanical splices for application in precast concrete connections
2. To investigate the performance of a precast concrete column with threaded mechanical splices

1.3 Scope of Study

This research covers the following scope of work:

1. Couplers with a steel grade of SS400 are used
2. 20mm diameter steel reinforcing bars with a nominal yield strength of 500 MPa are used
3. The column is scaled in according to the Standard Drawing of Rural Road Department

1.4 Literature Review

1.4.1 Monotonic and Cyclic Tests of Steel Bars

Cosenza and Prota (2006) constructed the experimental investigation on the compressive behavior of smooth bars at different values of L/D ratio, where L is the restraint distance and D is the bar diameter. The specimens were tested under both tension and compression. The analytical modeling for stress-strain relation under compression was then proposed from the ranging of (L/D = 5 to L/D>20). From the test result, the changes in tension behavior under variation of L/D are very slightly. However, the stress-strain relationship of compressive bars depends on the L/D ratio. It was not affected by the bar diameter. The bars with L/D<5 are assumed to be identical to the tensile behavior. The compressive strain-stress curves are depicted in Figure 1.3.

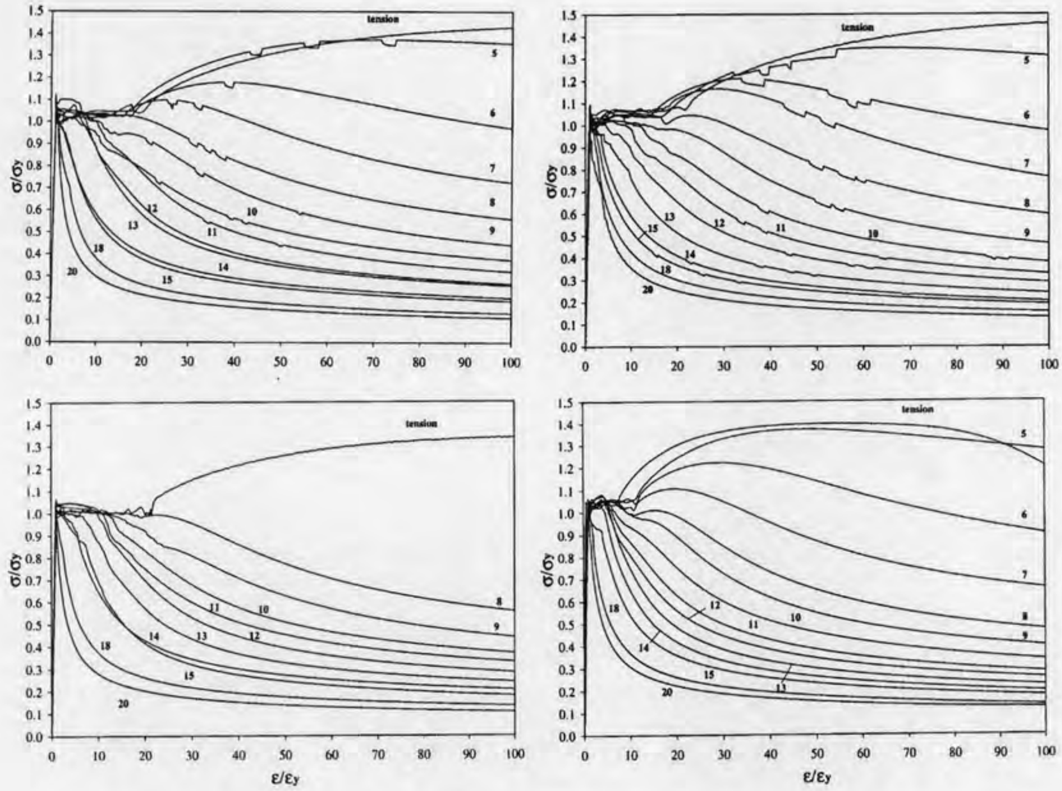


Figure 1.3 Compressive stress-strain curves

Dhakal and Maekawa (2002) discussed the importance of mechanisms that may weaken the seismic performance of reinforced concrete structures. It was stated that in estimating the response ductility of reinforced concrete members, average stress-strain relationships of concrete and reinforcing bar together with the analysis of spalling and buckling behaviors were necessary.

In addition, the length-to-diameter ratio of a reinforcing bar is a factor affecting its average compressive response. The probable buckling length is predetermined using geometrical and mechanical properties. The effect of lateral ties on the strength of reinforcing bar and the interdependency between concrete cover spalling and reinforcement buckling were accounted for. A theoretical technique of determining the buckling length was proposed using stability analysis. The process entails computation of the actual stiffness of a lateral tie, the minimum transverse stiffness at the tie locations under various buckling modes using energy methods and the buckling length by solving for the product of stable buckling mode and tie spacing.

1.4.2 Application of Mechanical Splice

Ancon (2005) offers four types of reinforcing bar couplers consist of tapered thread, Bartec, Bar X-L and MBT couplers as shown in Figure 1.4. Each coupler requires a different fixing method. The tapered thread coupler is designed to fit the applications which require joining reinforcing bars. A square cut at the ends of the rebar are usually made and a tapered thread is cut onto the bar in order to match the coupler. The sleeve is tightened onto the bar end using a calibrated torque wrench. The Bartec system is described as one of the smallest and most cost-effective coupler systems. The ends of the bars are enlarged and a parallel thread is sliced onto its ends in order to fit the coupler. A pipe or a chain wrench is used so as to assemble the coupler. For Bar X-L couplers, a square cut is also made at the ends of the bars. Then, a parallel thread is rolled onto the ends to suit the sleeve. To install the coupler, a piper or a chain wrench can be used. This type of couplers is appropriate where fatigue is an issue. MBT couplers are employed where it is not convenient to have the bar ends prepared for Bartec or other tapered thread couplers. Two serrated saddles within the coupler support the bars and are locked in place by a series of lock shear bolts.

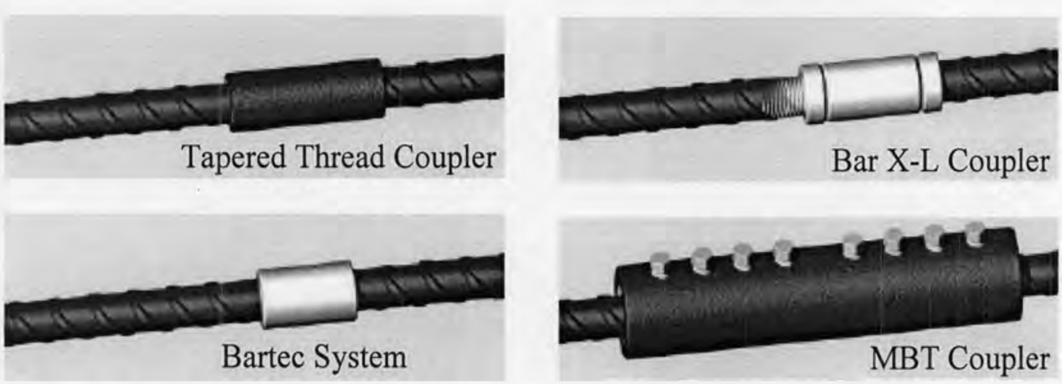


Figure 1.4 Types of mechanical splices (Ancon Building Products, 2005)

The mechanical rebar splices of ERICO, a leading designer and manufacturer of taper-threaded and splicing systems, are designed to meet the national and international codes of regulatory organizations. Some of the applications of these products include repair maintenance of a nuclear containment structure, series application to base plate, steam generator change out in a nuclear power plant, shear wall and precast application. These are depicted in Figure 1.5. (ERICO, 2006)

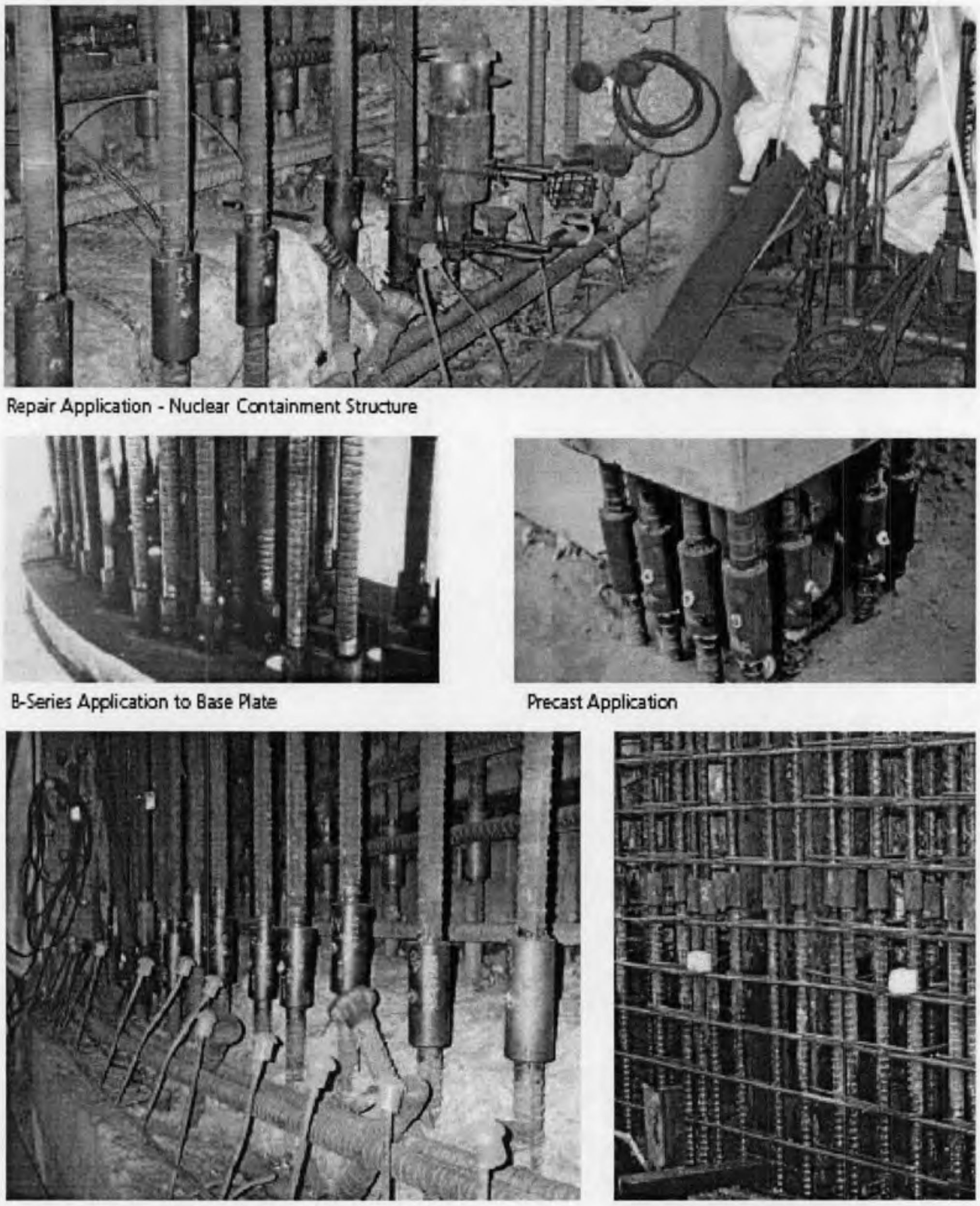


Figure 1.5 Applications of mechanical splices (ERICO, 2006)

1.4.3 Precast Column Constructions

In recent years, researches on precast concrete bridge substructure elements have been conducted. Billington *et al.* (1999) presented a precast segmental pier system developed for the Texas Department of Transportation for use as an alternative to cast-in-place concrete in non-seismic regions. This system consists of three principal components: column components, a template component, and an inversed-T cap-beam component, as shown in Figure 1.6. With this system, bridge columns were constructed by stacking multiple, column segments on the top of one another. After the columns were in place, the template component was placed on the top of the columns, and finally the cap-beam was placed on the template. The column segments, template, and cap-beam were match-cast with epoxy joints to minimize on-site construction time. Figure 1.7 shows the potential configurations for their proposed system.

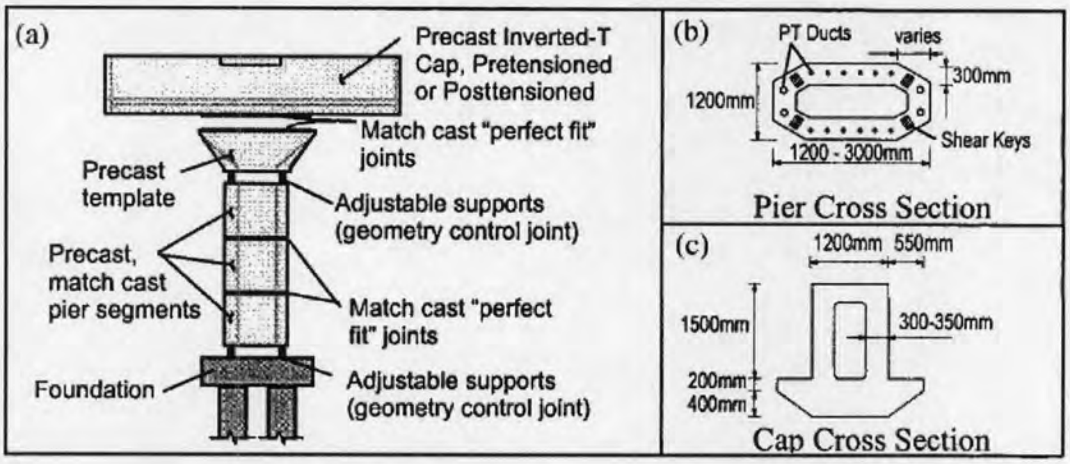


Figure 1.6 Elements of precast segmental pier (Billington *et al*, 1999)

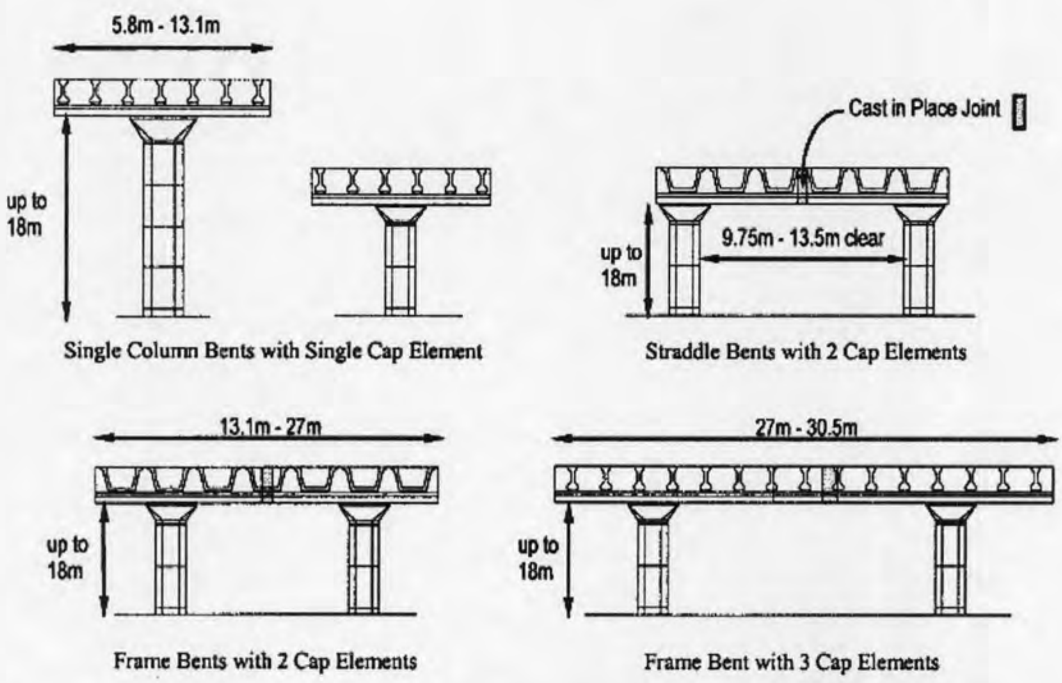


Figure 1.7 Configurations of the precast substructure system (Billington *et al*, 1999)

Figure 1.8 shows for the erection process of the proposed system

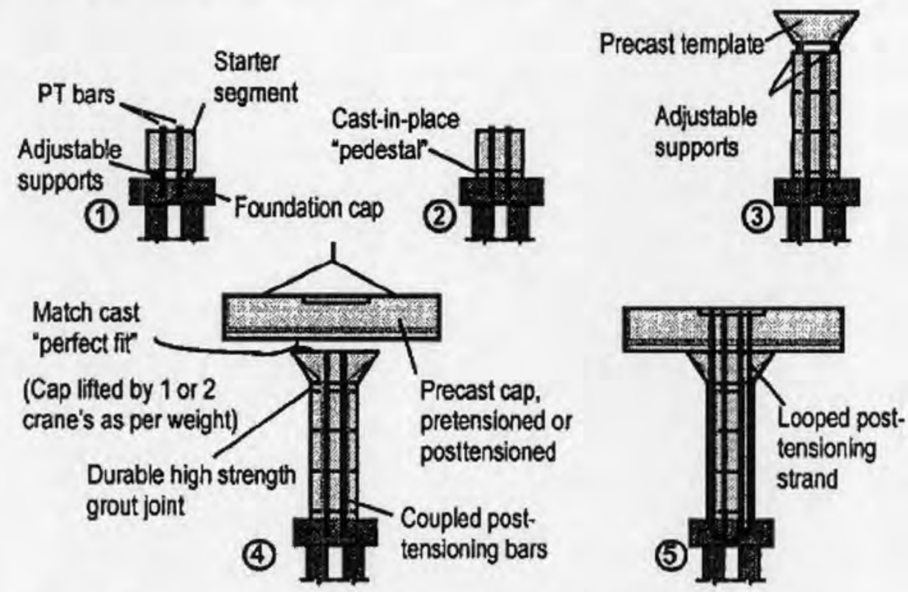


Figure 1.8 Erection sequence of precast pier (Billington *et al*, 1999)

Hieber *et al.* (2005) compared two pre-cast concrete bridge pier systems for rapid construction of bridges in seismic regions. The first one is a reinforced concrete system in which mild steel deformed bars were connected to precast concrete components as depicted in Figure 1.9. The other system is the hybrid system which uses a combination of unboned post-tensioning and mild steel deformed bars to make the connections as illustrated in Figures 1.10. The proposed footing-to-column connections of both systems are shown in Figures 1.11.

A parametric study is conducted using the nonlinear finite element method to investigate global response and likelihood of damage for various configurations of two systems subjected to a design level earthquake. The results of parametric study suggested that the systems had the potential for good seismic performance. The displacement ductility significantly increases with the axial-load ratio, and is independent of the column aspect ratio. For the hybrid frame, as the re-centering ratio increases, the displacement ductility remains unchanged. The reinforced concrete frames had slightly larger displacement ductility demands than the hybrid frames. Comparison of performance is shown in Table 1.1.

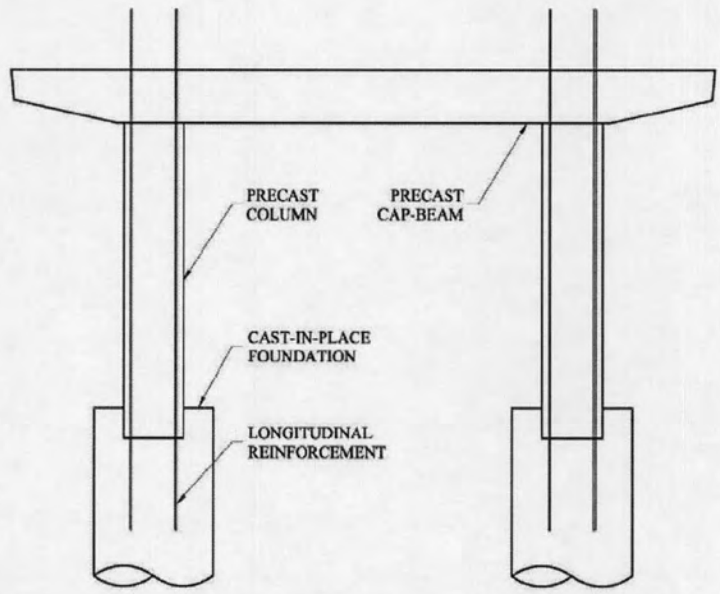


Figure 1.9 Elevation of reinforced concrete system pier (Hieber *et al.*, 2005)

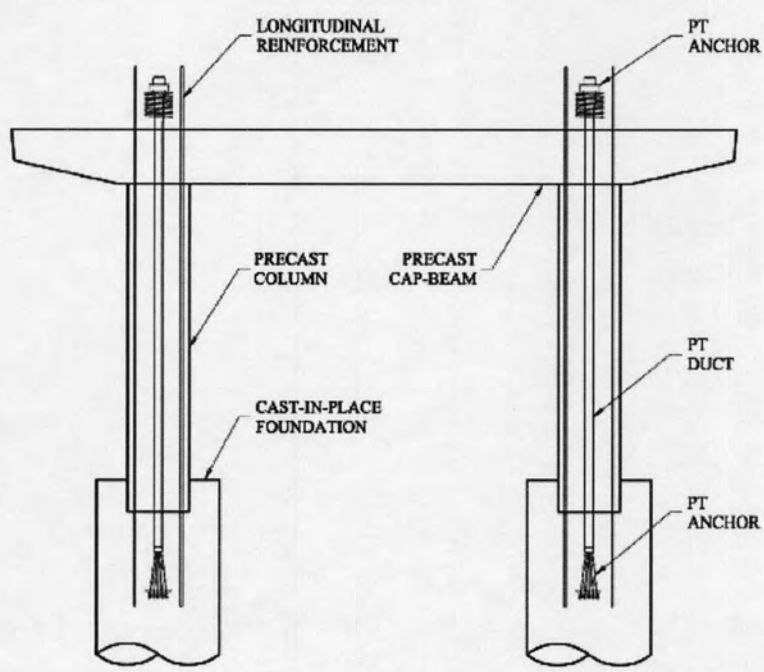
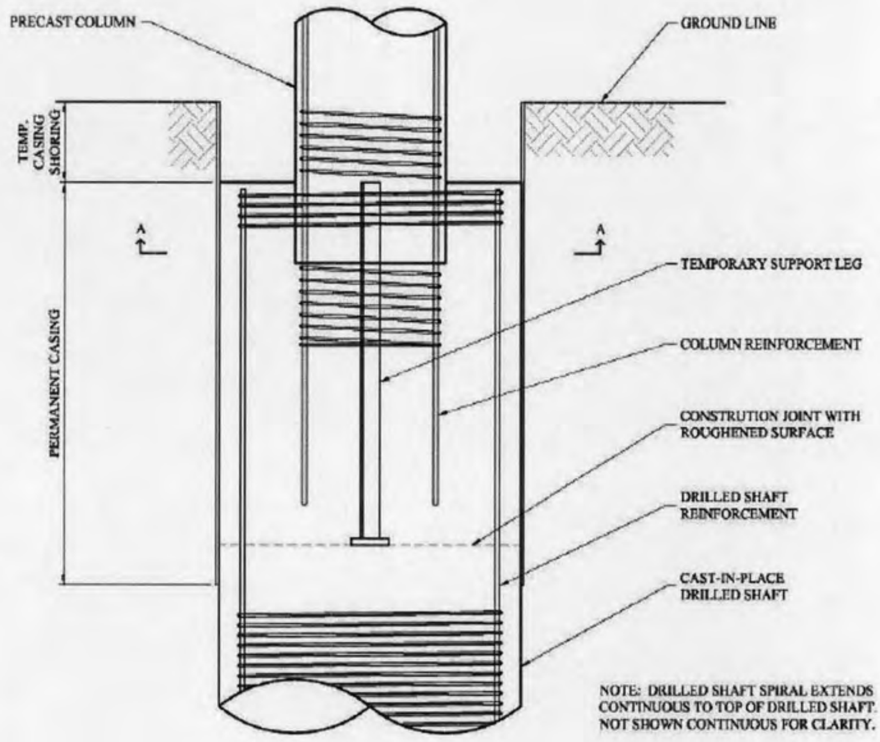
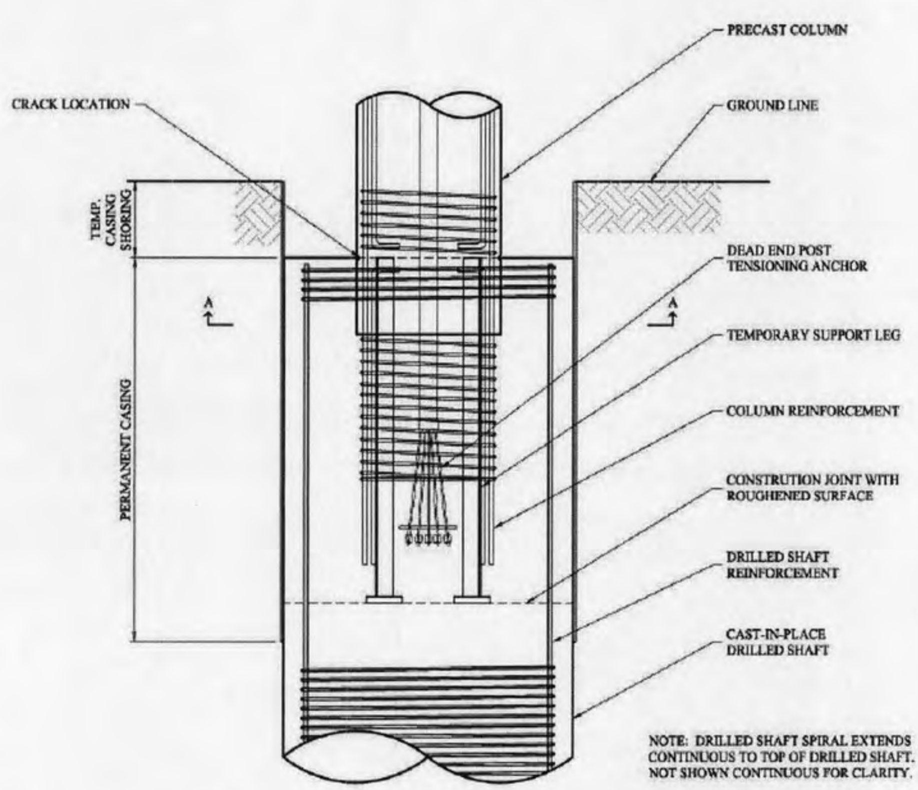


Figure 1.10 Elevation of hybrid system pier (Hieber *et al.*, 2005)



(a) Reinforced concrete system



(b) Hybrid system

Figure 1.11 Proposed footing-to-column connections for reinforced concrete and hybrid frames (Hieber *et al.*, 2005)

Table 1.1 Comparison of performance of reinforced concrete and hybrid frames (Hieber *et al.*, 2005)

	Reinforced Concrete Frame	Hybrid Frame	Percent Difference
$\frac{k_{cracked}}{k_{uncracked}}$	0.276	0.369	34%
$\frac{\Delta_y}{L_{col}}$	0.58%	0.41%	29%
F_{max}	429 kips	382 kips	11%
$\frac{\Delta_{max}}{L_{col}}$	2.14%	2.26%	6%
$\frac{\Delta_{max}}{\Delta_y}$	3.69	5.51	49%
P_{spall}	0.33	0.40	21%
P_{bb}	0.0030	0.0037	23%
ε_{sti}	0.026	0.020	23%
$\frac{\Delta_{max}}{\Delta_{ult}}$	0.26	0.27	4%

Figure 1.12 shows the construction sequence employed in the hybrid frame system.

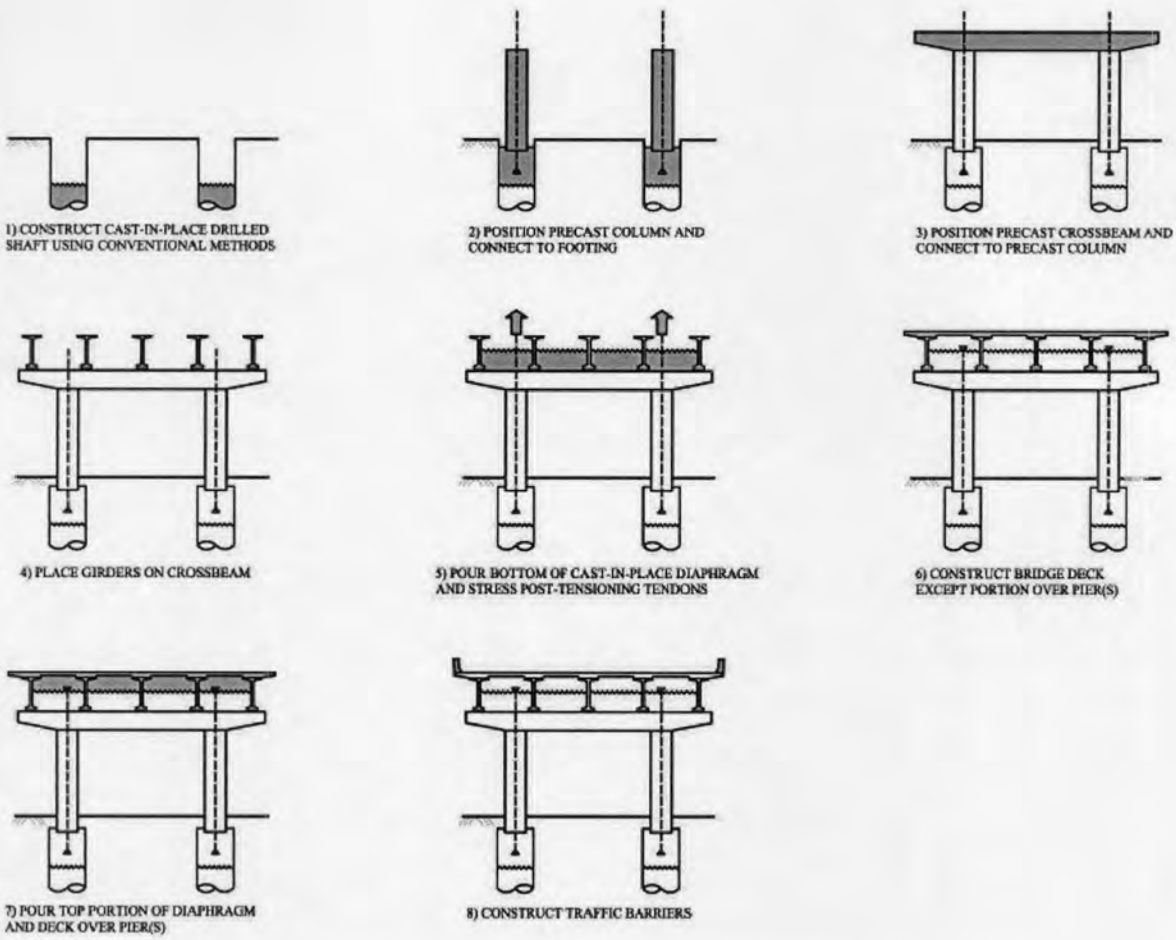


Figure 1.12 Proposed construction sequence for hybrid frames (Hieber *et al.*, 2005)

The pre-fabricated precast concrete bridge system is considered suitable for use in Alabama. For the past few years, the Federal Highway Administration has been actively promoting this system to state departments of transportation in Alabama in order to decrease construction times for bridge projects (Fouad *et al.*, 2006). Figure 1.13 shows the pre-fabricated precast concrete system developed by the Alabama Department of Transportation and referred to as the University of Alabama at Birmingham (UAB) precast bridge system. Dowels are projected to the top of the precast columns and are extended vertically upward into grouted sleeve couplers. These couplers are precast into the bent caps. It should be noted that the procedures followed in connecting the columns to the foundations are the same steps to be utilized in order to connect these bent caps to the columns. The connection is completed once grouting of the sleeves is done. (Fouad *et al.*, 2006)

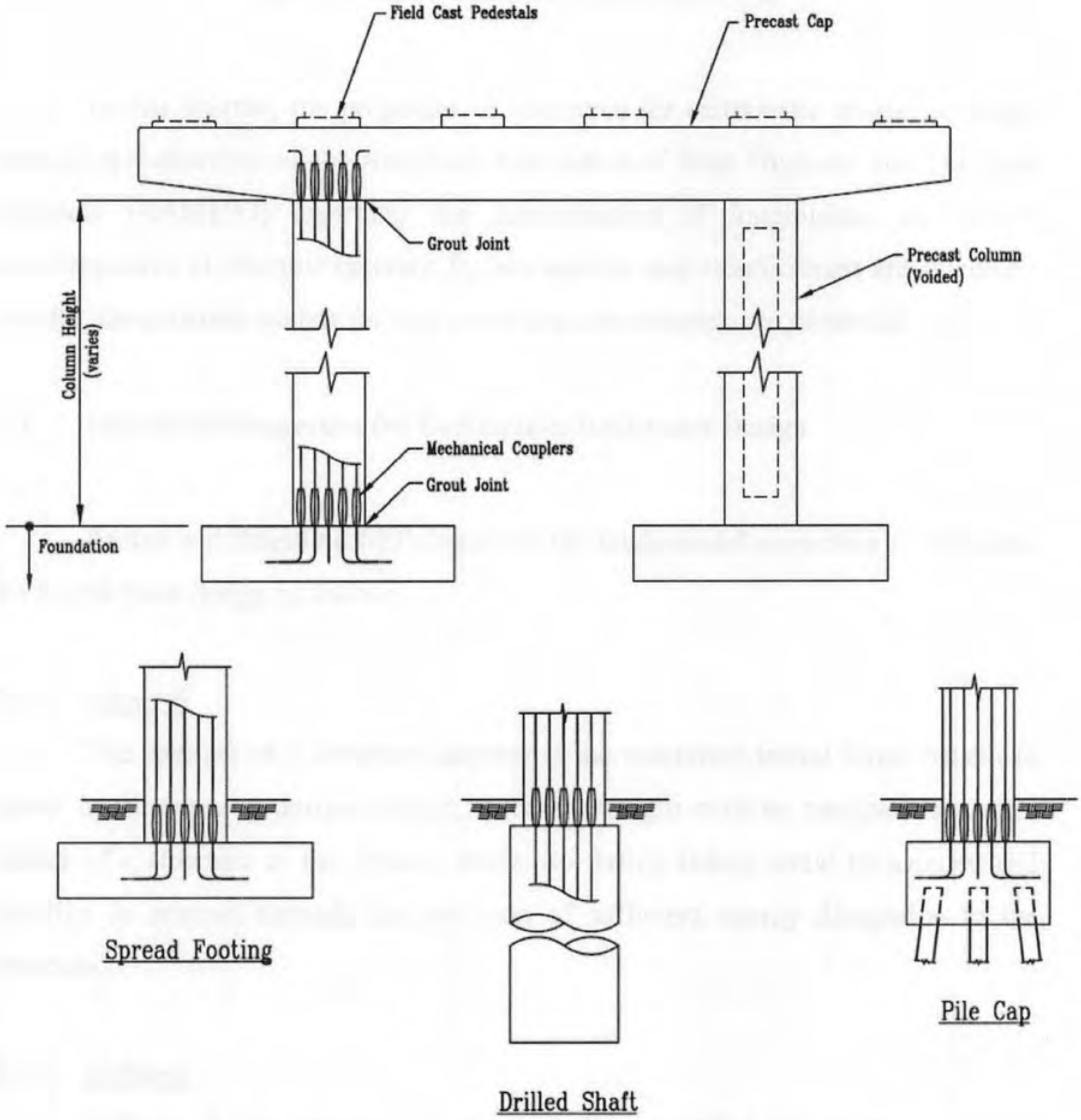


Figure 1.13 Precast bridge system: precast bent assembly and foundation types