CALTRANS *N*EXT *G*ENERATION *B*RIDGE

26th Annual US-Japan Workshop

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Abstract

The future of California bridges is a complex consideration due to variations in seismicity, geography, and user needs. The Federal Highway Administration's interest in the Accelerated Bridge Construction (ABC) program has encouraged innovation in many areas of research. Testing of new precast concrete systems may offer additional alternatives for California bridges. Upcoming and ongoing bridge research undertaken by the California Department of Transportation, Division of Structures, focuses on such systems. Highlights of how these tests are helping the Department meet its future transportation goals are reviewed.

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Introduction

Bridge designers face many challenges in the State of California – from complex widening or replacement projects in Southern California and the Bay Area, to extreme environmental constraints in the northern and coastal regions. While the cast-in-place prestressed (CIP P/S) box girder bridge has dominated California for half a century, structural challenges are not always best served by conventional solutions. Many factors play a role in finding the best bridge solution and some of these are beyond designer control. It is important to recognize that bridge designers have an obligation to help clients choose the best solution for any particular project. This requires early and continuous involvement. It also means being able to recognize that the lowest cost solution or the client's first solution may not be the best.

It is also important to recognize advancements that have taken place with California's large toll bridge projects. These include building structures off line and moving them into place with short road closures (Bay Bridge), construction of deep large diameter shafts in waterways for segmental construction (Benicia), rapid precast construction (San Mateo), and utilizing seismic isolation devices on a large scale (Dumbarton). Caltrans is also currently completing numerous in-house segmental bridge designs. These are a small sample of recent accomplishments, but represent projects where newer ideas were successfully implemented on structures that will serve into the distant future.

NGB Effort

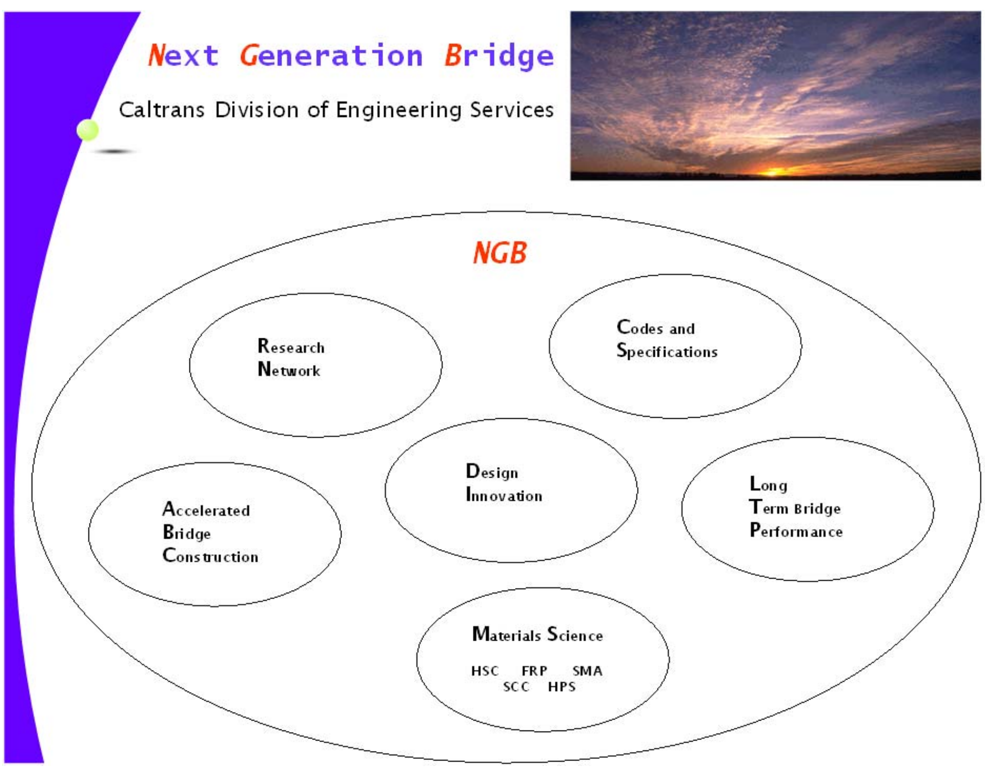
In September of 2008 Caltrans assembled a group of engineers to consider what form California's next generation bridges (NGB) might take. This group became two internal teams. The first team was to discuss, brainstorm, and create bridge design concepts. To encourage a balanced point of view, the engineers represented design, foundations, earthquake engineering, and construction disciplines within the Department. A specific charter was not set so that a free flow of ideas would be encouraged. The second team was tasked with evaluation of the proposed new concepts and/or suggested modifications to procedures.

Discussions brought forth many concepts. Some centered on bridge materials. Can shape memory alloys (SMA) or fiberglass reinforced plastic (FRP) be successfully incorporated into standard bridges? What are the appropriate locations to place self consolidating concrete (SCC) and high strength concrete (HSC)? Will high strength steel become the new standard? Other conversations led to components. Use of column base elastomers, micropiles, concrete filled tubes (CFT), and alternate deck concretes came to light. Support and framing systems were also discussed. How can abutment shear keys be anchored to perform in California if the structure is supported on mechanically stabilized earth (MSE) foundations? What about methods and management support? What is the best way to determine where accelerated bridge construction (ABC) is really appropriate? How can we make life cycle cost estimates a more reliable decision tool? Is it possible to standardize designs in California where seismic demand varies so much? If procedures are changed will they be appropriately followed by required software and training?

Though this exchange was healthy, it became clear that the next generation bridge (NGB) is a moving target that requires an ongoing effort. To simplify the arenas of discussion, six major points were noted. Caltrans' NGB would –

- Consider all bridge types
- Consider speed of construction
- Consider variety of materials
- Test to validate new ideas
- Develop supporting codes and specifications
- Consider maintenance

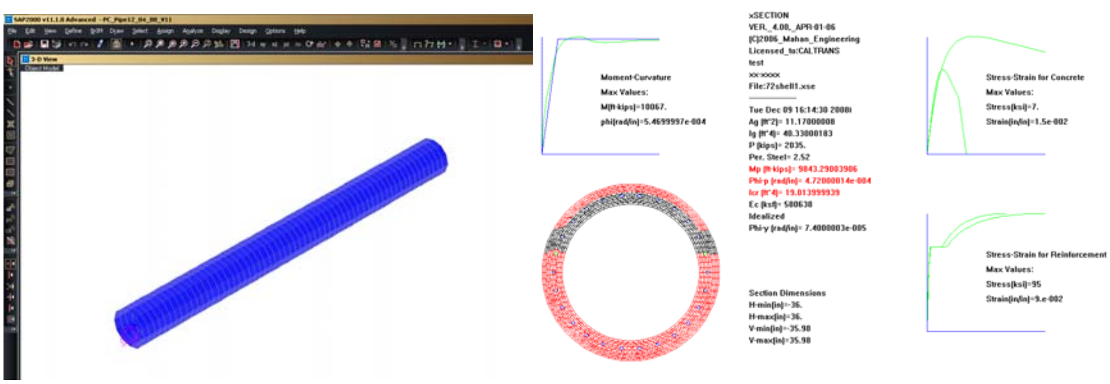
These points should work together to lead to the best solution at each bridge site. The key to NGB is not necessarily a specific new bridge type or new construction method, but is more likely dependent upon a well educated and trained staff, a constructive arena for ideas, and methods to implement ideas quickly.



Minimum Expectations

Caltrans NGB needed to be more than lofty goals and generalizations. The team needed a starting point that made sense. Precast (PC) systems were targeted first because it appeared they might provide the quickest benefit. This was spurred on by the grouted splice-sleeve concept being used in Georgia, Utah, and other states primarily in the eastern and southern U.S. whereby PC column bases were joined to poured-in-place footings via couplers. It was desired to investigate the possibility of such a system yet consider California's high seismicity.

The viability of precast columns was to be tackled first. The main focus was on ensuring that ***any precast systems should emulate the seismic performance of current cast-in-place systems***. Regarding construction, shipping, erection, and safety, it was estimated that a six foot (1.8m) diameter hollow concrete section up to 60 feet (18.3m) long similar to a culvert could be produced, trucked, and erected by standard highway legal equipment and means. Such a shell, if connected properly, could then be filled on site to create a solid column.

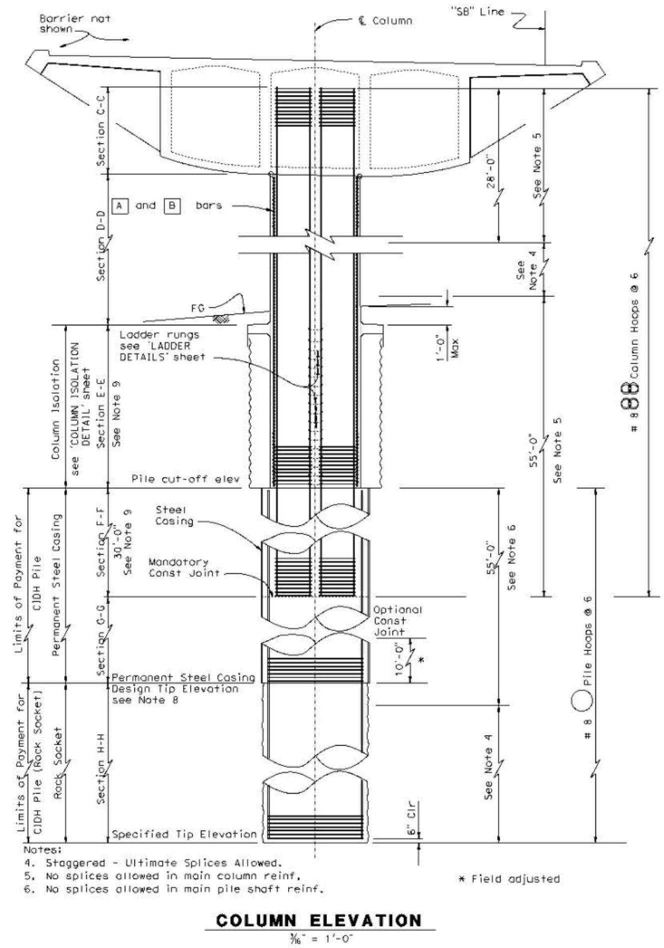


PC Column Transportation and Erection Viability Analysis

The concept of reinforcement splices in a plastic hinge zone would be a clear deviation from the Departments' standard seismic practice. Caltrans Seismic Design Criteria section 8.1.1 currently states,

> "Splicing of flexural reinforcement is not permitted in critical locations of ductile elements. The 'no splice' region shall be the greater of: The length of the plastic hinge region as defined in Section 7.6.3 or the portion of the column where the moment demand exceeds M_y. A 'no splice' region shall be clearly identified on the plans for both hinge locations or fixed-fixed columns."

The detail below is from a recently designed structure and features 55 foot (16.8m) long no-splice zones in the expected plastic hinge regions.



Example of Standard Caltrans no splice zones

For the PC system to function properly, a fixed base precast column would need to meet the high ductility requirements of seismic regions. Most of the confinement would need to be in the precast member with bottom of column hoops placed in the joint region during erection. The real key was examining the possibility of using ultimate couplers (those that consistently develop the ultimate strength of the bar) at the column base connection.

As part of concept verification, a suite of five connection details were developed for further investigation. They cover the standard types of substructure systems at Caltrans. Testing for comparison to CIP equivalents would be essential if such details were ever to be adopted.

Precast Column Connection Detail No. 1 – for fixed base column to footing
Precast Column Connection Detail No. 2 – for Type I pile shafts
Precast Column Connection Detail No. 3 – for Type II pile shafts
Precast Column Connection Detail No. 4 – for fixed column to cap connections
Precast Column Connection Detail No. 5 – for pin base column connections

These details (attached) were scrutinized by members of the NGB Review Team, PC industry representatives, and presented at seismic workshops for preliminary comments. The first connection detail was submitted for the Caltrans 2009 Seismic Research Proposal cycle. The University of Nevada at Reno is scheduled to conduct this research in fall of 2010. Actual test protocol is to be determined during specimen development. It is expected that the outcome of these tests will be used to assess the need for further research and analysis prior to making any policy or design standard changes.

Additional Research

Another research contract pertaining to bridges of the future is being carried out at Iowa State University through the University of California San Diego laboratory. Led by Rick Snyder and Associate Professor Sri Sritharan from Iowa State, this research involves a modified version of an inverted 'T' bent cap resting under precast girders. The development of positive moment capacity through bottom chord post tension anchorage is one of the focal points of this study.

Iowa State University Inverted 'T' Bent Cap Testing

The University of Washington is also conducting a study for Caltrans on the feasibility of Concrete Filled Tubes (CFT) for use as bridge columns. Anchorage is provided via a spiral welded flanged pipe anchored into a voided footing. Associate Professor Dawn Lehman and Professor Charles Roeder from the Civil and Environmental Engineering Department who are heading this work envision that this detail, inverted, may also be used for a bent cap connection. This could prove especially useful on multi-column bents which are pinned at the base.

University of Washington CFT Testing

Conclusion

The five attached test concept detail sheets depict one possible view of California's Next Generation Bridge. These may one day form the framework for future details that designers could use on a site specific basis. The above research contracts represent an investment of over $1.3M toward new concept viability, reduced construction time, and ensured performance of California's bridges. By investing in the development of new details and testing these systems, Caltrans is preparing to meet its future transportation needs to "Improve Mobility Across California".

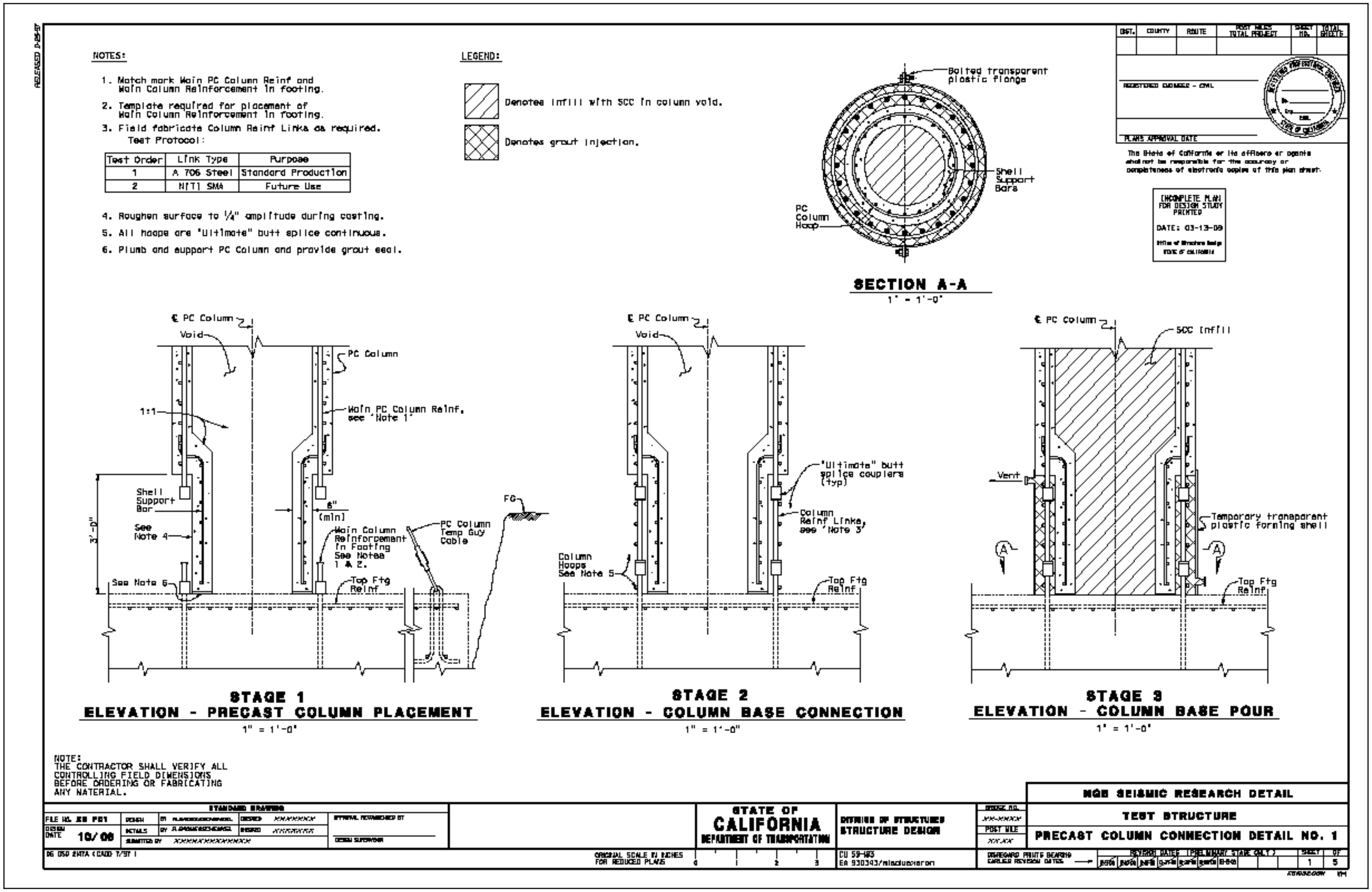
NGB Team Membership

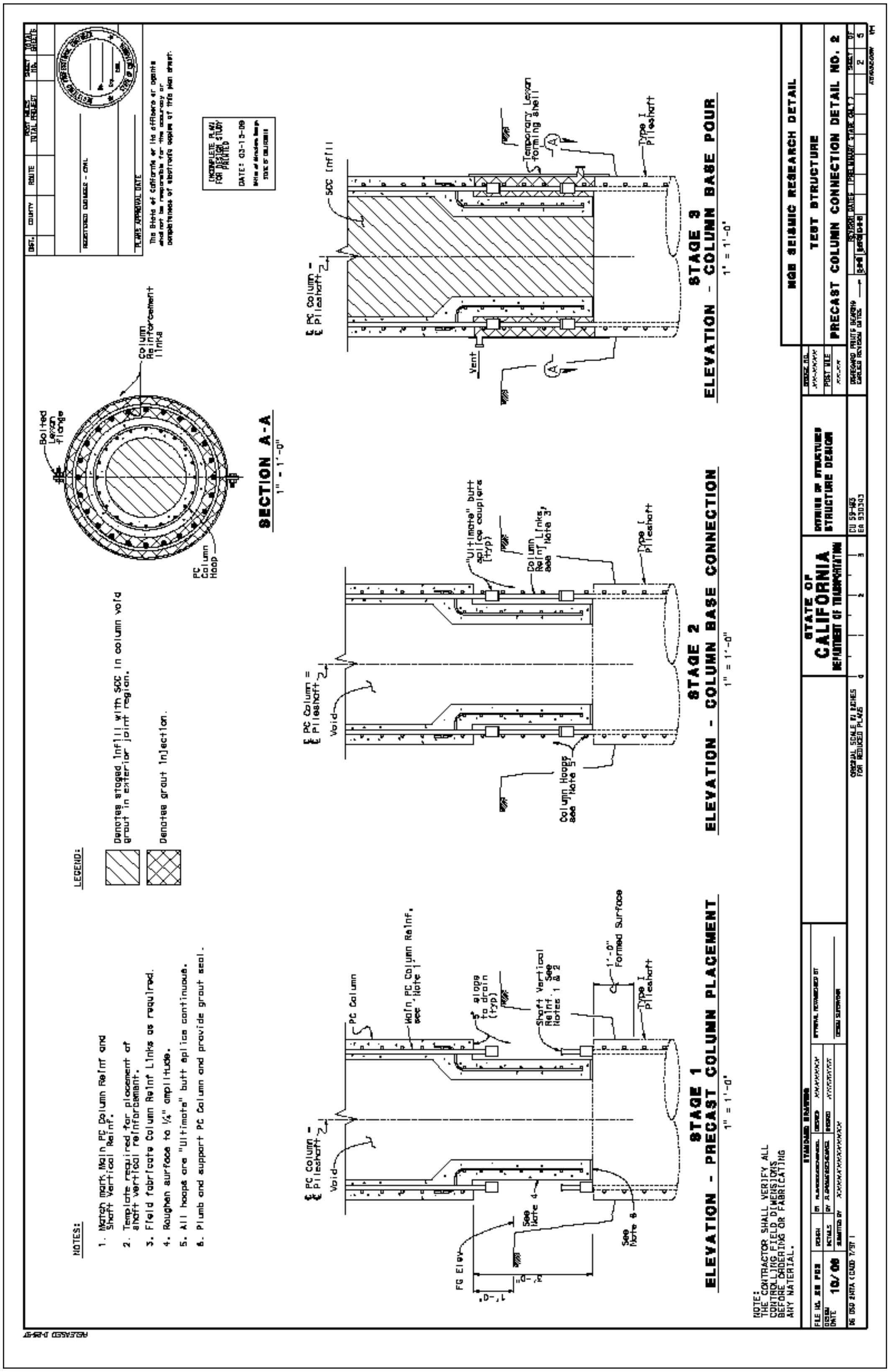
Development Team:

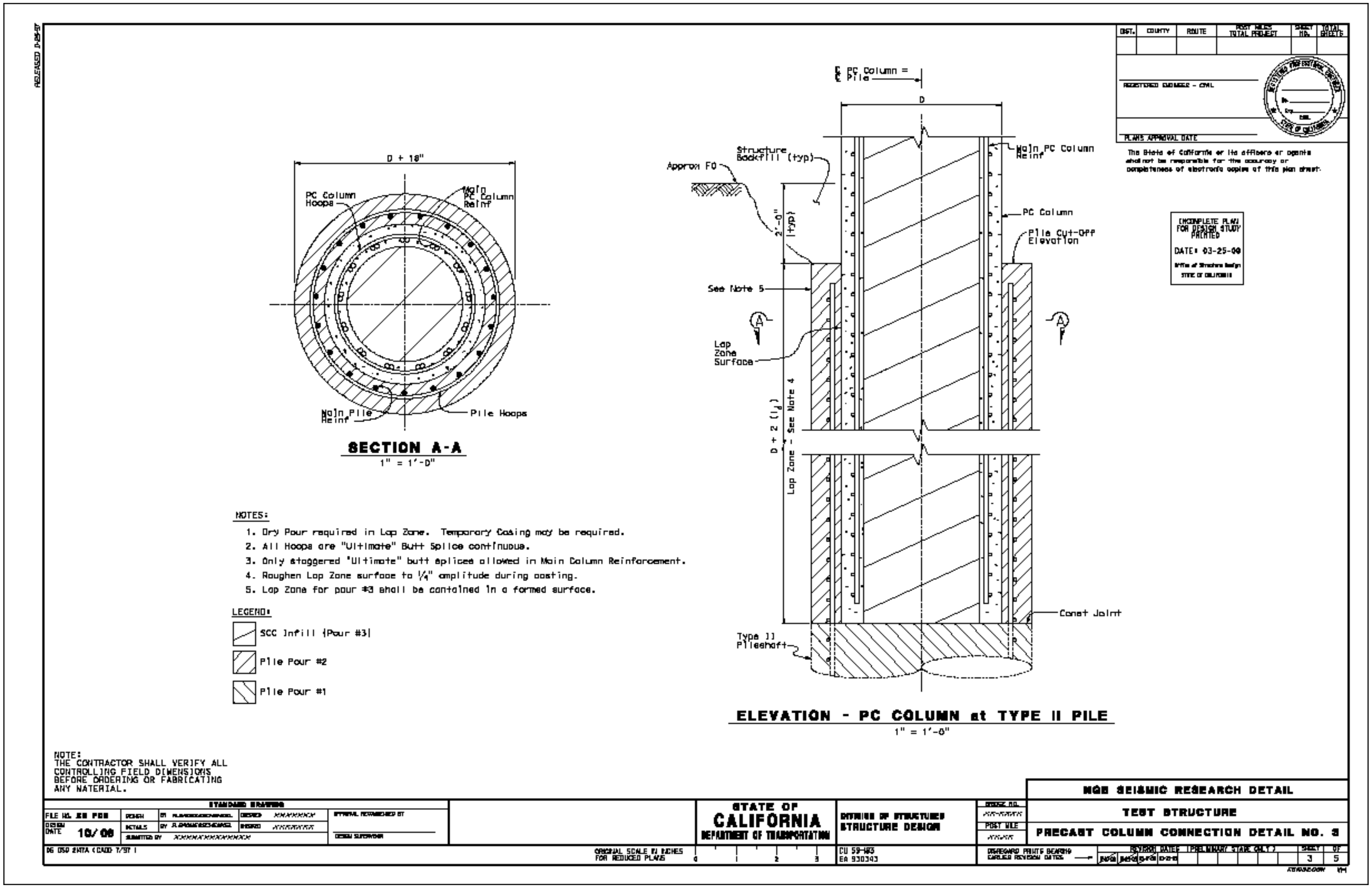
Joey Aquino
Ron Bromenschenkel
Mike Keever
John Lammers
Mark Mahan
Angel Perez-Cobo
Talal Sadek
Gudmund Setberg
Tom Shantz

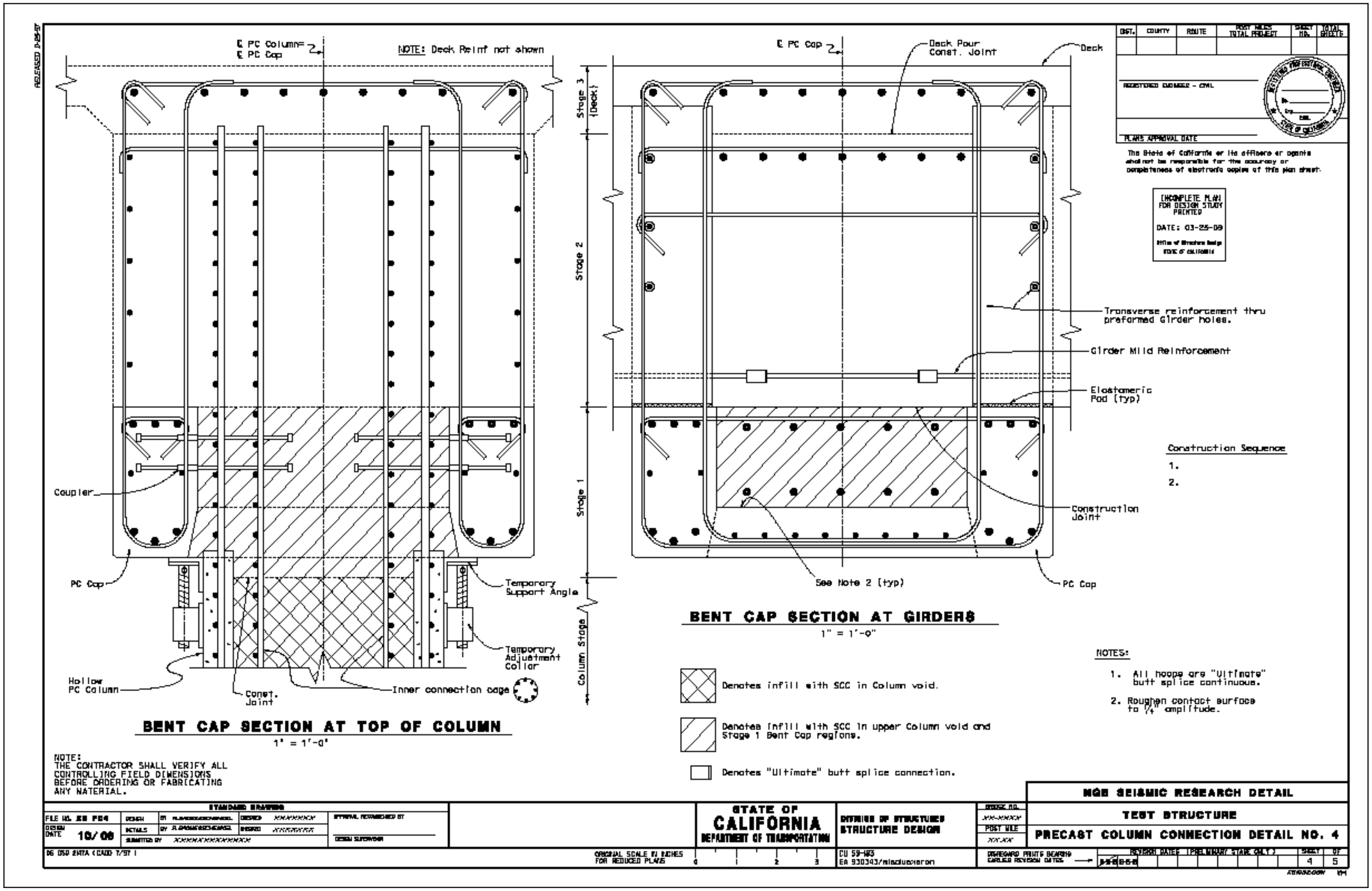
Review Team:

Paul Chung
Joe Downing
Mike Keever
Steve Wiman


NOTES:
1. Match mark Main PC Column Reinf and Main Column Reinforcement in footing.
2. Template required for placement of Main Column Reinforcement in footing.
3. Field fabricate Column Reinf Links as required. Test Protocol:
Test Order | Link Type | Purpose
1 | A 706 Steel | Standard Production
2 | NiTi SMA | Future Use
4. Roughen surface to 1/4" amplitude during casting.
5. All hoops are "Ultimate" butt splice continuous.
6. Plumb and support PC Column and provide grout seal.
LEGEND:
Denotes infill with SCC in column void.
Denotes grout injection.
Bolted transparent plastic flange
Shell Support Bars
PC Column Hoop
SECTION A-A
1" = 1'-0"
REGISTERED ENGINEER - CIVIL
PLANS APPROVAL DATE
The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.
INCOMPLETE PLAN FOR DESIGN STUDY PRINTED
DATE: 03-13-09
℄ PC Column
Void
PC Column
1:1
Main PC Column Reinf, see Note 1
Shell Support Bar
See Note 4
See Note 6
3'-0"
8" (min)
Main Column Reinforcement in Footing See Notes 1 & 2.
Top Ftg Reinf
PC Column Temp Guy Cable
FG
STAGE 1
ELEVATION - PRECAST COLUMN PLACEMENT
1" = 1'-0"
"Ultimate" butt splice couplers (typ)
Column Reinf Links, see Note 3
Column Hoops See Note 5
STAGE 2
ELEVATION - COLUMN BASE CONNECTION
1" = 1'-0"
SCC Infill
Vent
Temporary transparent plastic forming shell
STAGE 3
ELEVATION - COLUMN BASE POUR
1" = 1'-0"
NOTE:
THE CONTRACTOR SHALL VERIFY ALL CONTROLLING FIELD DIMENSIONS BEFORE ORDERING OR FABRICATING ANY MATERIAL.
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES
STRUCTURE DESIGN
NGB SEISMIC RESEARCH DETAIL
TEST STRUCTURE
PRECAST COLUMN CONNECTION DETAIL NO. 1
10/08
ORIGINAL SCALE IN INCHES FOR REDUCED PLANS
CU 59-HR3
EA 930343/miscluxceron
SHEET 1 OF 5


NOTES:
1. Match mark Main PC Column Reinf and Shaft Vertical Reinf.
2. Template required for placement of shaft vertical reinforcement.
3. Field fabricate Column Reinf Links as required.
4. Roughen surface to ¼" amplitude.
5. All hoops are "Ultimate" butt splice continuous.
6. Plumb and support PC Column and provide grout seal.
LEGEND:
Denotes staged infill with SCC in column void grout in exterior joint region.
Denotes grout injection.
STAGE 1
ELEVATION - PRECAST COLUMN PLACEMENT
1" = 1'-0"
STAGE 2
ELEVATION - COLUMN BASE CONNECTION
1" = 1'-0"
STAGE 3
ELEVATION - COLUMN BASE POUR
1" = 1'-0"
SECTION A-A
1" = 1'-0"
NOTE:
THE CONTRACTOR SHALL VERIFY ALL CONTROLLING FIELD DIMENSIONS BEFORE ORDERING OR FABRICATING ANY MATERIAL.
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
NGB SEISMIC RESEARCH DETAIL
TEST STRUCTURE
PRECAST COLUMN CONNECTION DETAIL NO. 2


SECTION A-A
1" = 1'-0"
D + 18"
PC Column Hoops
Main PC Column Reinf
Main Pile Reinf
Pile Hoops
ELEVATION - PC COLUMN at TYPE II PILE
1" = 1'-0"
℄ PC Column = ℄ Pile
D
Structure Backfill (typ)
Approx FG
2'-0" (typ)
See Note 5
Lap Zone Surface
D + 2 (l_d)
Lap Zone - See Note 4
Main PC Column Reinf
PC Column
Pile Cut-Off Elevation
Const Joint
Type II Pileshaft
NOTES:
1. Dry Pour required in Lap Zone. Temporary Casing may be required.
2. All Hoops are "Ultimate" Butt Splice continuous.
3. Only staggered "Ultimate" butt splices allowed in Main Column Reinforcement.
4. Roughen Lap Zone surface to 1/4" amplitude during casting.
5. Lap Zone for pour #3 shall be contained in a formed surface.
LEGEND:
SCC Infill (Pour #3)
Pile Pour #2
Pile Pour #1
NOTE:
THE CONTRACTOR SHALL VERIFY ALL CONTROLLING FIELD DIMENSIONS BEFORE ORDERING OR FABRICATING ANY MATERIAL.
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES
STRUCTURE DESIGN
MGB SEISMIC RESEARCH DETAIL
TEST STRUCTURE
PRECAST COLUMN CONNECTION DETAIL NO. 3
INCOMPLETE PLANS FOR DESIGN STUDY PRINTED
DATE: 03-25-09
PLANS APPROVAL DATE
REGISTERED ENGINEER - CIVIL
DESIGN DATE 10/08
ORIGINAL SCALE IN INCHES FOR REDUCED PLANS
CU 59-103
EA 930343



RELEASED 10-25-07
℄ PC Column=
℄ PC Cap
NOTE: Deck Reinf not shown
Coupler
PC Cap
Temporary Support Angle
Temporary Adjustment Collar
Hollow PC Column
Const. Joint
Inner connection cage
BENT CAP SECTION AT TOP OF COLUMN
1" = 1'-0"
NOTE:
THE CONTRACTOR SHALL VERIFY ALL CONTROLLING FIELD DIMENSIONS BEFORE ORDERING OR FABRICATING ANY MATERIAL.
Stage 3 (Deck)
Stage 2
Stage 1
Column Stage
℄ PC Cap
Deck Pour Const. Joint
Deck
Transverse reinforcement thru preformed Girder holes.
Girder Mild Reinforcement
Elastomeric Pad (Typ)
Construction Joint
See Note 2 (Typ)
PC Cap
BENT CAP SECTION AT GIRDERS
1" = 1'-0"
Denotes infill with SCC in Column void.
Denotes infill with SCC in upper Column void and Stage 1 Bent Cap regions.
Denotes "Ultimate" butt splice connection.
Construction Sequence
1.
2.
NOTES:
1. All hoops are "Ultimate" butt splice continuous.
2. Roughen contact surface to 1/4" amplitude.
DIST. COUNTY ROUTE POST MILES TOTAL PROJECT SHEET NO. TOTAL SHEETS
REGISTERED ENGINEER - CIVIL
PLANS APPROVAL DATE
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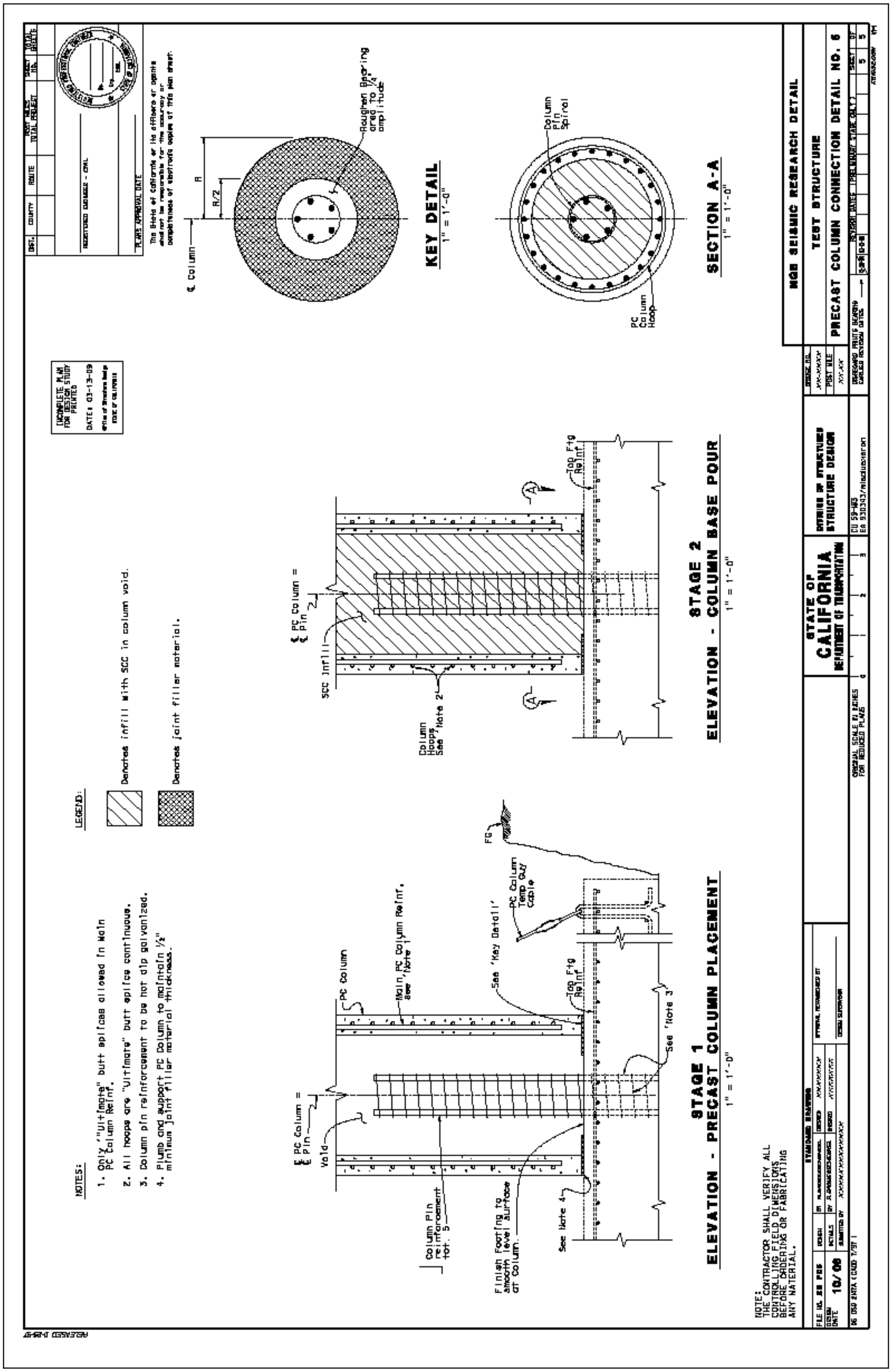
INCOMPLETE PLAN FOR DESIGN STUDY PRINTED
DATE: 03-25-09
STANDARD DRAWING
FILE NO. EE FE4
DESIGN DATE 10/08
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES
STRUCTURE DESIGN
ORIGINAL SCALE IN INCHES FOR REDUCED PLANS
CU 59-4103
EA 930343/misc
NGB SEISMIC RESEARCH DETAIL
TEST STRUCTURE
PRECAST COLUMN CONNECTION DETAIL NO. 4
SHEET 4 OF 5


NOTES:
1. Only "Ultimate" butt splices allowed in Main PC Column Reinf.
2. All hoops are "Ultimate" butt splice continuous.
3. Column pin reinforcement to be hot dip galvanized.
4. Plumb and support PC Column to maintain ½" minimum joint filler material thickness.
LEGEND:
Denotes infill with SCC in column void.
Denotes joint filler material.
INCOMPLETE PLAN FOR DESIGN STUDY PRINTED
DATE: 03-13-09
PC Column = Pin
Void
PC Column
Main PC Column Reinf. See 'Note 1'
Column Pin reinforcement tot. 5
Finish Footing to smooth level surface at Column.
See 'Key Detail'
PC Column Temp Guy Cable
FG
See Note 4
Top Ftg Reinf
See 'Note 3'
STAGE 1
ELEVATION - PRECAST COLUMN PLACEMENT
1" = 1'-0"
SCC Infill
Column Hoops See 'Note 2'
STAGE 2
ELEVATION - COLUMN BASE POUR
1" = 1'-0"
Column
R
R/2
Roughen Bearing area to ¼" amplitude
KEY DETAIL
1" = 1'-0"
Column Pin Spiral
PC Column Hoop
SECTION A-A
1" = 1'-0"
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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES
STRUCTURE DESIGN
NQB SEISMIC RESEARCH DETAIL
TEST STRUCTURE
PRECAST COLUMN CONNECTION DETAIL NO. 5
DESIGN DATE 10/08
ORIGINAL SCALE IN INCHES FOR REDUCED PLANS
CU 59-183
EA 930343/misclubsieron
5 5