A P P E N D I C E S

NCHRP 12-105

App. A – Survey of State Departments of Transportation

App. B – Proposed AASHTO/ASTM Standard Test Method for Bar Couplers

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APPEBDIX A

Survey of State Departments of Transportation/Federal Agencies/Bridge Design Consulting Firms on Familiarity and Implementation of ABC Column Connections

An online survey of state DOT bridge/structures divisions and bridge design consulting firms was conducted from 10/21/2015 to 11/23/2015 to collect data on familiarity, past deployment, available design guideline and examples, and potential future application of ABC techniques for precast bridge columns. An email was sent to the members of the AASHTO 2013 Subcommittee on Bridges and Structures, state departments of transportation, federal agencies, as well as bridge design consulting firms across the US. A total of 221 individuals were contacted, of whom 50 individuals from 44 agencies and 33 states responded. The survey form and statistical analysis of the survey results are presented in this appendix.

A.1 Blank Survey Form

The following is the introductory material and the survey form.

The National Cooperative Highway Research Program (NCHRP) recently awarded a contract to the University of Nevada, Reno under NCHRP 12-105 to develop proposed AASHTO displacement-based design and construction specifications for implementation of ABC column connections (http://wolfweb.unr.edu/homepage/saiidi/NCHRP/SeismicSpecs/index.html). The connections include, but are not limited to: mechanical bar splices, grouted ducts, and pockets/sockets. A short survey of current practice in ABC connections is being conducted as part of the study. We would like to kindly request that you assist us by completing the survey form.

The purpose of the survey is to explore the past, present, and planned future application of ABC column connections in the US bridges, conduct a statistical analysis, and help determine details of the future phases of NCHRP 12-15.

We very much appreciate your time and effort in providing the information.

1. Are you or other staff in your agency familiar with the following ABC column connections?

	0 (Not at all)	1	2	3	4	5 (Very familiar)
Mechanical Bar Splices	○	○	○	○	○	○
Grouted Duct	○	○	○	○	○	○
Pocket or Socket	○	○	○	○	○	○
Pipe-Pin	○	○	○	○	○	○
Rocking	○	○	○	○	○	○
Connections w/ Advanced Materials	○	○	○	○	○	○

2. Do you or other staff in your agency know any other connection type(s) for precast bridge columns?
○ Yes ○ No

Connection Type 1 _____

Connection Type 2 _____

Connection Type 3 _____

How familiar are you with the connection(s) you listed?

	0 (Not at all)	1	2	3	4	5 (Very familiar)
Connection Type 1	○	○	○	○	○	○
Connection Type 2	○	○	○	○	○	○
Connection Type 3	○	○	○	○	○	○

3. Has your agency ever used any type of ABC column connections?
○ Yes ○ No

If yes, please select connection type(s):
☐ Mechanical Bar Splices ☐ Grouted Ducts ☐ Pocket/Socket ☐ Pipe-Pin ☐ Rocking ☐ Connections w/ Advanced Materials ☐ Other connection types

Please briefly explain why the **connection** was selected for construction:

Mechanical Bar Splices

Grouted Ducts

Pocket/Socket

Pipe-Pin

Rocking

Connections w/ Advanced Materials

Other connection types

Please briefly explain the **construction issues** you dealt with:

Mechanical Bar Splices

Grouted Ducts

Pocket/Socket

Pipe-Pin

Rocking

Connections w/ Advanced Materials

Other connection types

Please briefly explain the **inspectability issues** you dealt with:

Mechanical Bar Splices

Grouted Ducts

Pocket/Socket

Pipe-Pin

Rocking

Connections w/ Advanced Materials

Other connection types

Please briefly explain the **maintenance issues** you dealt with:

Mechanical Bar Splices

Grouted Ducts

Pocket/Socket

Pipe-Pin

Rocking

Connections w/ Advanced Materials

Other connection types

4. Does your agency plan to use ABC column connections in the next four years?
○ Yes ○ No
Please select connection type(s):
☐ Mechanical Bar Splices ☐ Grouted Ducts ☐ Pocket/Socket ☐ Pipe-Pin ☐ Rocking ☐ Connections w/ Advanced Materials ☐ Other connection types

5. Has your agency published design guidelines specific to ABC column connections?
○ Yes ○No
Please provide a reference (or a link to access):
Mechanical Bar Splices

Grouted Ducts

Pocket/Socket

Pipe-Pin

Rocking

Connections w/ Advanced Materials

Other connection types

6. Has your agency published ABC column connection design examples?
○ Yes ○ No
Please provide a reference (or a link to access):
Mechanical Bar Splices

Grouted Ducts

Pocket/Socket

Pipe-Pin

Rocking

Connections w/ Advanced Materials

Other connection types

7. The most important reason that your agency preferred using ABC column connections over conventional cast-in-place construction is:
○ Time Saving ○ Cost Saving ○ Both

8. What is the seismicity of your state?
○ AASHTO SDC A ○ AASHTO SDC B ○ AASHTO SDC C ○ AASHTO SDC D

Please provide your contact information

First Name

Last Name

Company

Email

State

A.2 Survey Results

The survey was sent to the members of the AASHTO 2013 Subcommittee on Bridges and Structures, state departments of transportation, federal agencies, as well as bridge design consulting firms across the US. A total of 221 individuals were contacted, of whom 50 individuals from 44 agencies and 33 states participated in the survey. Table A-1 presents the list of respondent agencies, who provided their affiliation. Summary of the collected data is presented in this section.

Table A-1. List of Survey Participant

Type	Name
Depart. of Transportation	Alabama; Arizona; Arkansas; California; Delaware; Florida; Hawaii; Illinois; Iowa; Maine; Maryland; Massachusetts; Michigan; Minnesota; Missouri; Nebraska; New Hampshire; New York State; North Carolina; North Dakota; Ohio; Oregon; South Dakota; Tennessee; Utah; Virginia; Washington State; Wisconsin; Wyoming
Design/Consulting Firm	TTG Engineers; NCM Engineering Corporation; Moffatt & Nichol; Kleinfelder; Quincy Engineering, Inc.; HDR Engineering; CME Associates, Inc.; HNTB; VHB; Arora and Associates; E. L. Robinson Engineering Co.; Fish & Associates Inc.

A.2.1 Familiarity with ABC Column Connections

The familiarity of bridge engineers with six ABC column connections, mechanical bar splice connections, grouted duct connections, pocket connections, pipe-pin connections, rocking connections, and connections with advanced materials, was evaluated. Figure A-1 shows the familiarity of the individual participants with these connection types. Darker colors indicate less familiarity with each connection.

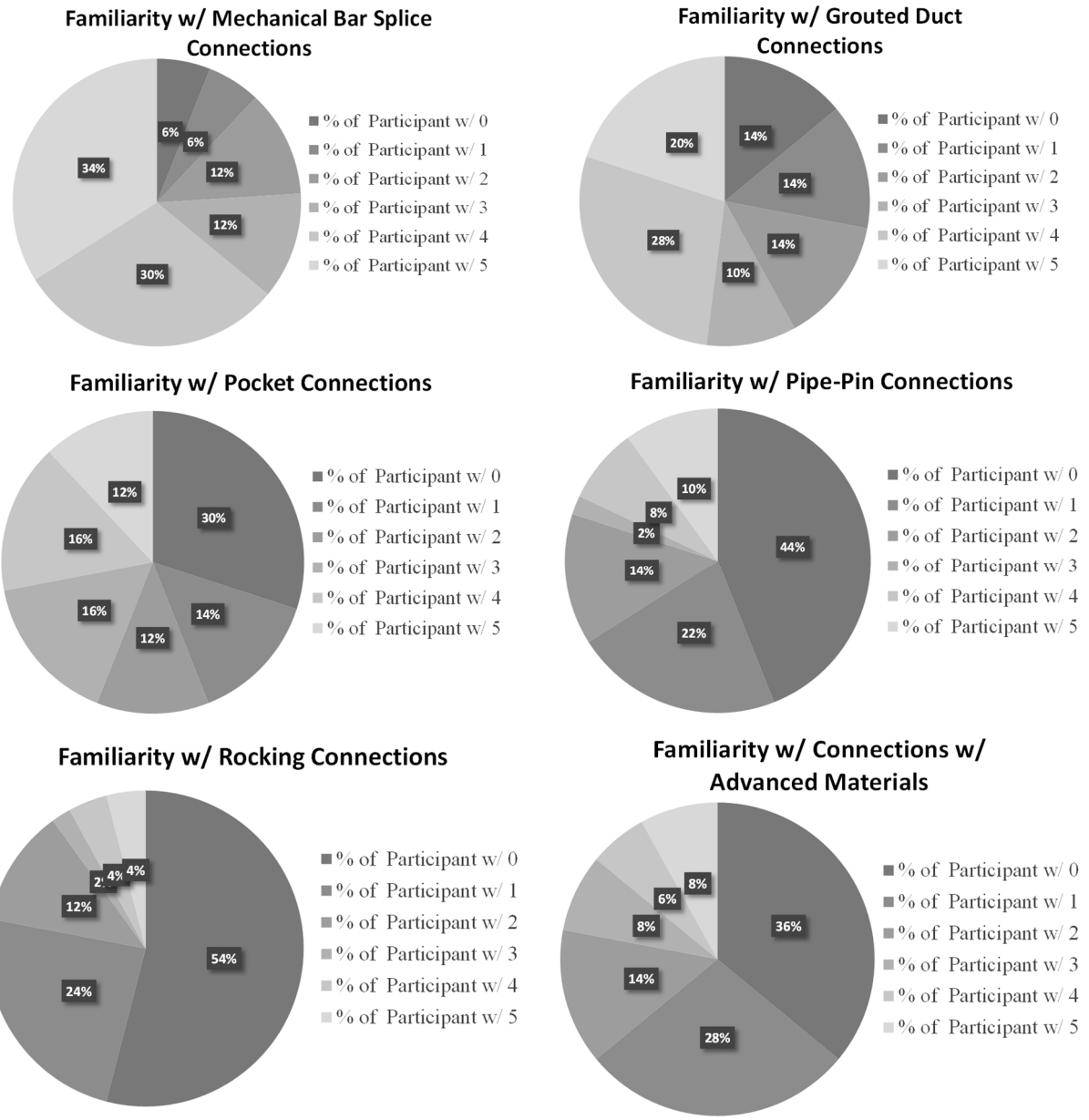

Figure A-1. Participant familiarity breakdown with ABC column connections (0 is unfamiliar)

It can be seen that bridge engineers are most familiar with mechanical bar splice connections. The second and third most known connection types in the bridge engineering community are respectively grouted duct connections and pocket connections. Rocking connections, connections with advanced materials, and pipe-pin connections are new to bridge engineers.

A.2.2 Past Application of ABC Column Connections

It was found that 57% of the participating agencies have incorporated one or more type/s of ABC column connections (Fig. A-2). It can be seen that mechanical bar splice, grouted duct, and pocket connections have been utilized more than other connection types. Table A-2 presents the reasons why the participating agencies preferred these precast column connections over conventional construction. Comments provided

by different agencies were separated by semicolon. In general, mechanical bar splice connections (mainly grouted couplers) were utilized since they are easy to build, fast , proof tested, available in the market, familiar to designers and contractors, and relieve congestion. Grouted duct and pocket connections were incorporated by these agencies mainly because they are very fast and easy to construct, are usually used in low demand regions, and are proof tested. However, pocket connections offer better tolerance than grouted ducts. Pipe-pin connections were utilized since they prevent moment transfer and are easy to build. The provided information was used in Chapter 1.

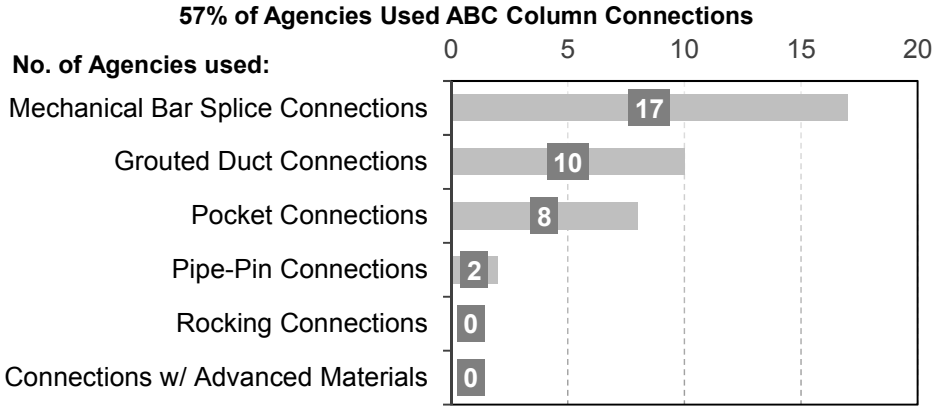

Figure A-2. Past application of ABC column connections

Table A-2. Agency justifications to use ABC column connections

Connection Type	Agency Comments
Mechanical Bar Splices	Ease of construction and performance; Contractor familiarity; Long history of their use and performance testing results; NMB splices on Edison Bridge in Fort Myers; Relieved congestion and fast erection; Relatively fast and has been tested (grouted couplers); Provides structural integrity, reduced rebar congestion, reduced materials cost; Good performance, ease of use, contractors seem to like; Grouted couplers are most common for connecting vertical dowels; Ease of construction; Availability and familiarity; Short length; ABC Speed
Grouted Duct	Ease of construction; US90 Over Little River 2-Column Pier to Cap connection; Fast, ease of use by contractor; Only option which was available 12 years ago; Allows for development of reinforcing steel in duct; Used in post tensioned segments; Low demand area; Previous research and satisfactory performance; Based on information from other states; Appeared to be appropriate and usable by our industry
Pocket/Socket	Simplicity for construction; Full moment connection; Pile Pockets - Buckman Bridge, Reedy Creek; Fast and ample construction tolerances; Ease of use and design requirements were emulative; Simplicity to accommodate pipe pile bent with prefabricated cap, not as tight tolerance needed; Previous research and satisfactory performance
Pipe-Pin	Ease of construction and performance, pure pin action, no moment to superstructure, simple detailing
Rocking	Not used in past
w/ Advanced Materials	Not used in past

The participating agencies highlighted the construction challenges they dealt with regarding each ABC column connection as presented in Table A-3. The main issue pertaining to mechanical bar splice connections was the tight tolerance needed for bar alignments in couplers. Grouted ducts imposed congestion in cap beams, tight tolerance (but better then couplers), and need quality control for grouts. Alignment was the main concern of the participating agencies regarding pocket connections. These and other issues were discussed in Chapter 2.

Table A-3. Construction issues related to past ABC column connections

Connection Type	Agency Comments
Mechanical Bar Splices	Alignment of bar cage, orientation/placement of grout tubes; No real issues as long as tolerances were followed; Tight construction tolerance, proprietary products and expensive grout; Occasional misalignment but can usually be corrected; Expense, and clearances; Tight tolerance needed for connector locations, spacing and concrete consolidation; Fit up and alignment; Concern that the grouted couplers were not totally filled with the high strength grout, alignment of the bars and filling coupler completely
Grouted Duct	Very versatile, duct conflicts with cap reinforcing when dowels cast out of position; Grout flow rate sensitivity to temperature; Some trouble lining up the two members, crowds section for reinforcing in column; Quality control (QC) of post tensioning and grouting operation as well as the time taken to complete these operations; Field QC; Accuracy of bars location in the ducts
Pocket/Socket	Simple details; Concerns about large unreinforced grout widths when piles at maximum out of plan tolerance; Precast column and bent cap required coordination during construction and fabrication to ensure ducts lined up correctly; Need for headed bars; Correct placement of piles
Pipe-Pin	None
Rocking	Not used in past
w/ Advanced Materials	Not used in past

Table A-4 presents the inspectability issues of the ABC column connections. The main concern of the participating agencies was the quality of the grout used in grouted couplers, grouted ducts, or pocket connections. One agency was concerned about the reduced cover in mechanical bar splice connections (Table A-5) that may impose maintenance issues.

Table A-4. Inspectability issues related to past ABC column connections

Connection Type	Agency Comments
Mechanical Bar Splices	Proper grouting; Normal QC
Grouted Duct	Checking for the presence of voids in the duct are difficult and time consuming; Access and lack of full visual inspection; Vents for grouting and voids; Difficult to verify total filling
Pocket/Socket	None
Pipe-Pin	None
Rocking	Not used in past
w/ Advanced Materials	Not used in past

Table A-5. Maintenance issues related to past ABC column connections

Connection Type	Agency Comments
Mechanical Bar Splices	Reduced cover
Grouted Duct	None
Pocket/Socket	None
Pipe-Pin	None
Rocking	Not used in past
w/ Advanced Materials	Not used in past

A.2.3 Future Application of ABC Column Connections

Many agencies expressed interest in utilizing ABC column connections in new bridges with 64% planning to deploy in the next four years, when the final deliverables of the present study are due. Figure A-3 shows the number of agencies that will be using each connection type.

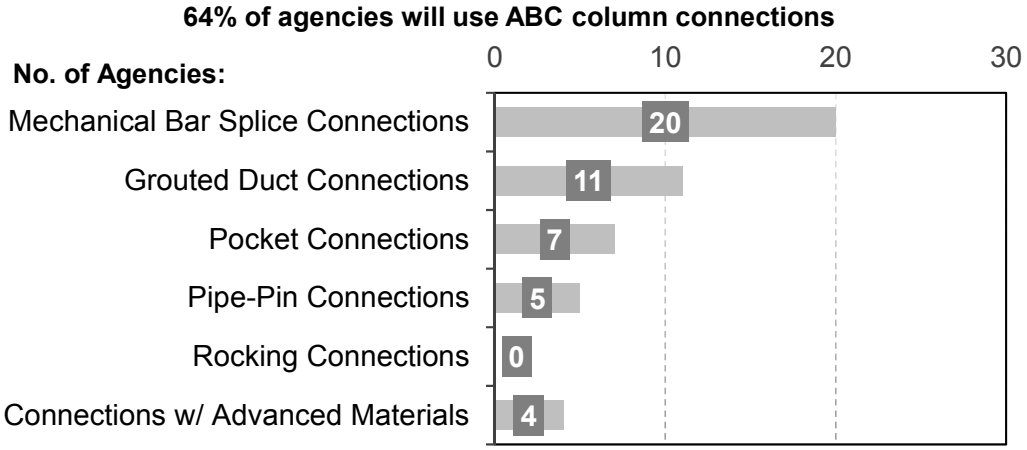

Figure A-3. Future application of ABC column connections

A.2.4 ABC Column Connection Design Guidelines and Examples

Of 44 agencies, only five have published design guidelines for one or two types of ABC column connections (Fig. A-4). Table A-6 presents the reference lists and links provided by the participants. Only three agencies have published design examples for precast column connections, some with examples in more than one connection type (Fig. A-5 and Table A-5). These documents will be reviewed in the present study and relevant specifications and detailing will be used in the development of design guideline.

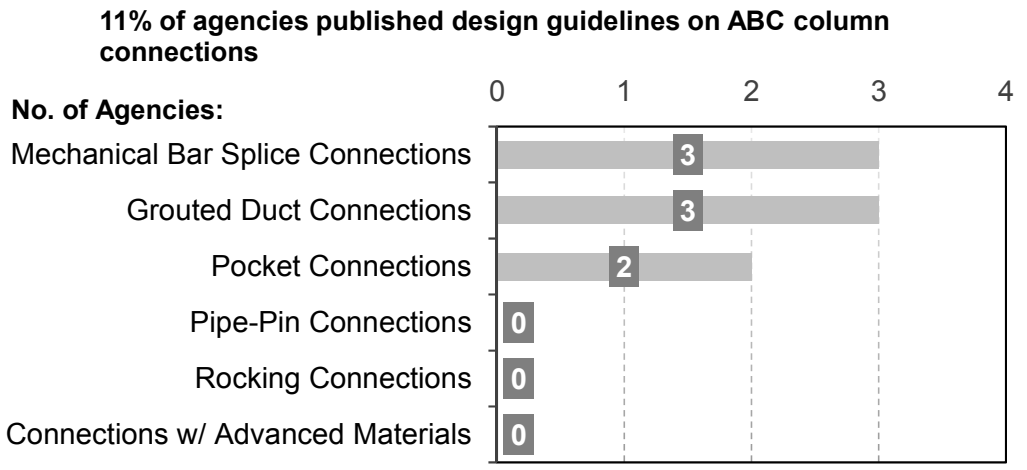

Figure A-4. Design guideline availability

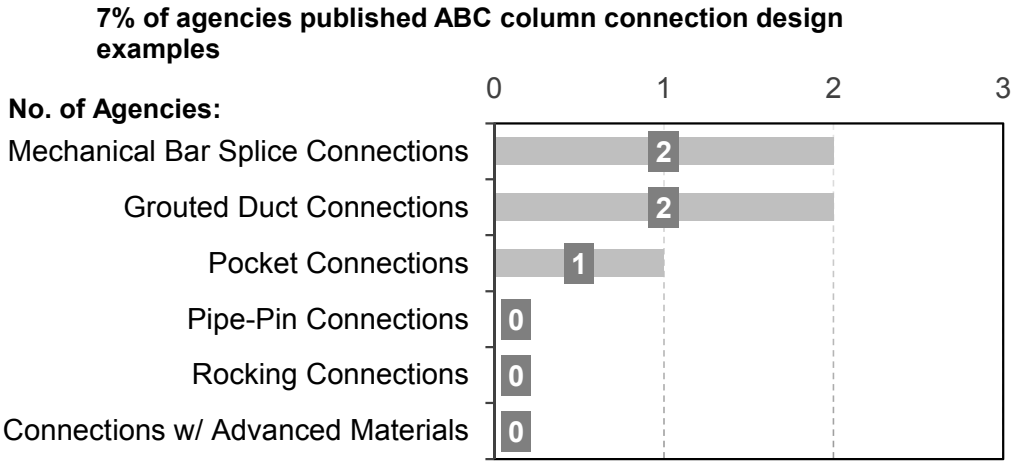

Figure A-5. Design example availability

Table A-6. Referred design guidelines and examples for ABC column connections

Connection Type	Design Guideline	Design Example
Mechanical Bar Splices	PCI Northeast Bridge Technical Committee Documents (www.pcine.org) http://www.dot.state.fl.us/structures/innovation/PBES.shtm UDOT developed a design guideline	http://www.dot.state.fl.us/structures/innovation/PBES.shtm WisDOT Bridge Manual, Chapter 7
Grouted Duct	http://www.dot.state.fl.us/officeofdesign/training/designexpo/2015/presentations/PBES-PrecastBentCapDevelopementAndImplementation-SteveNolan.pdf WisDOT Bridge Manual Chapter 7 WSDOT developed a design guideline	http://www.dot.state.fl.us/structures/innovation/PBES.shtm WashDOT developed an example
Pocket/Socket	Developmental Design Standards pending: Index 20700 series: http://www.dot.state.fl.us/rddesign/DS/Dev.shtm WSDOT developed a design guideline	WSDOT developed an example
Pipe-Pin	None	None
Rocking	None	None
w/ Advanced Materials	None	None

A.2.5 Why ABC Column Connections?

It was found that 69% of individual participants preferred ABC over conventional construction because of its time saving (Fig. A-6). The remaining 31% selected ABC because of the combined benefit of time and cost saving. However, no individual participant selected ABC solely for cost saving.

Figure A-7 shows the seismicity level of the participating states. It can be seen that the majority of the participating states were from none- and low-seismic regions but expressed an interest for ABC mainly because of time saving that it offers.

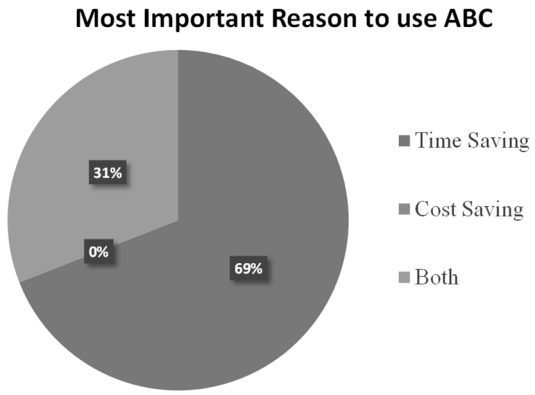

Figure A-6. Why ABC

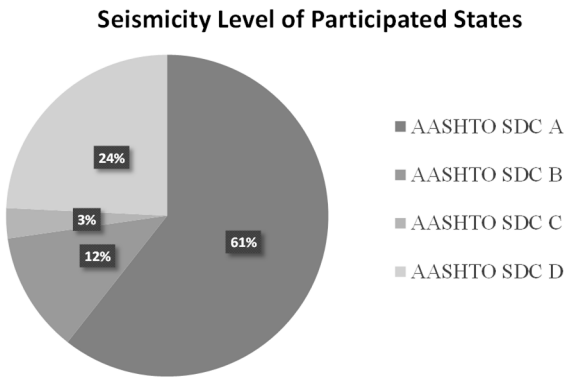

Figure A-7. Seismicity level of participating states

A.3 Conclusions

There is a clear correlation between the familiarity of bridge engineers with ABC column connections and the field application of these connections. For example, bridge engineering community is most familiar with mechanical bar splice connections (mainly grouted couplers), and the survey showed that this connection type has been utilized more than any other ABC connection types. The same trend was seen for future application of this connection type. Furthermore, the survey clearly indicates that the availability of design guidelines and examples is another motivation for field deployment. Since the main objective of the current project is to develop design guidelines and examples for ABC column connections, it is expected that successful execution of the NCHRP 12-105 project is likely to enable and encourage more engineers to consider deploying precast columns for new construction.