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C2/C3J Coupler Weld Evaluation for ACI-349 and AISC-N690 Requirements

Public Meeting

August 13, 2015



Outline & Objective

- Problem Statement & Summary of Conclusions
- Background Information
- Justification
 - Applicable Code Requirements
 - Determination of the Weld Acceptance Criteria
 - Phase I: Testing the coupler, weld, reinforcement bar system
 - Phase II: Testing the coupler weld to failure
 - Safety Margin
- Licensing Basis Impact



OBJECTIVE: Summarize the proposed resolution path for demonstrating coupler weld compliance with both AISC N690 and ACI 349 requirements through testing

Problem Statement & Summary of Conclusions

Problem Statement

- The design basis failed to demonstrate how the licensing basis requirement of the 125% ACI-349 strength evaluation is met for the coupler weld

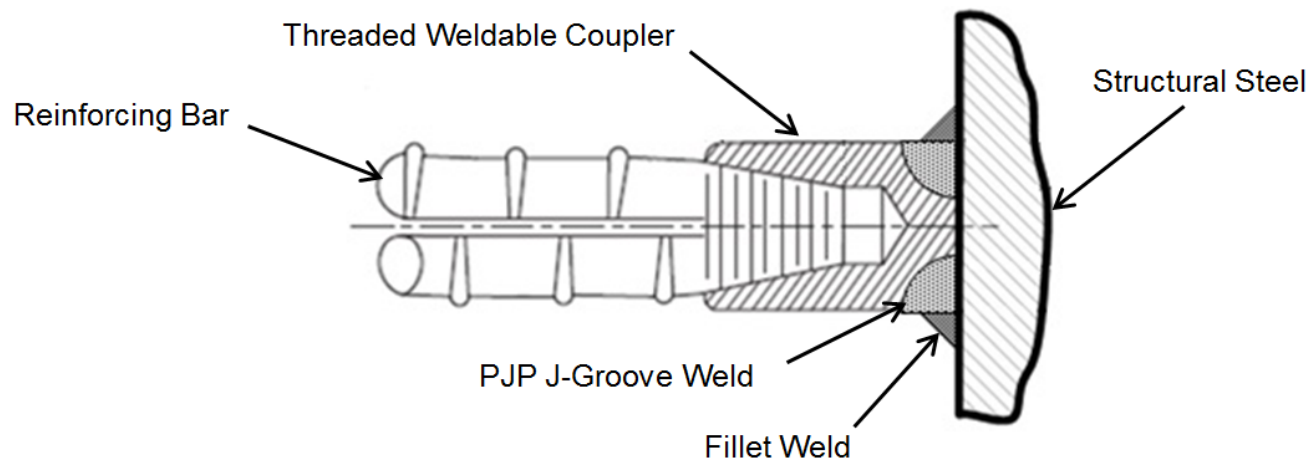
Resolution

- Proposed LAR demonstrates through testing the 125% ACI-349 strength evaluation for the coupler weld
 - Code compliant
 - Safety margin preserved
 - Covers both past and future welds (One design & licensing basis)
 - No Impact on shield building licensing basis and analysis



Background

- Weldable couplers are utilized in the AP1000 design where reinforcing bars are attached to structural steel
- The coupler mechanical connection consists of a reinforcing bar threaded at the end and a mechanical coupler
- The coupler is connected by a weld to the structural steel
 - The coupler is welded via a PJP J-Groove with fillet reinforcement



Lenton[®] C2/C3J Coupler

Background

- The design function of the couplers is to mechanically anchor reinforcing bars to structural steel.
- As specified in UFSAR subsection 3.8.4.5, “Structural Criteria,” the analysis and design of concrete and structural steel conform to ACI 349-01 and AISC N690-1994, respectively.

Applicable Code Requirements

- ACI 349-01 125% strength requirement:
 - Section 12.14.3.4 - A full mechanical connection shall develop in tension or compression, as required, at least 125% of specified yield strength f_y of the bar.
- ACI-349 requirements for mechanical anchorage in Section 12.6 reference Appendix B
 - Section 12.6.2 - Mechanical anchorages shall be designed in accordance with Appendix B - Steel Embedments
 - ACI 349-01 Appendix B does not provide weld requirements
- AISC-N690-1994 Section Q1.22 provides requirements for design of steel embedments permitted by ACI 349 Appendix B, including welds
- AISC-N690 Section Q1.22.2 provides requirements for justification of stress limits by testing
 - Section Q1.22.2.1.2 - Design limits less conservative than those specified in this section may be used by the Engineer if substantiated by experimental or detailed analytical investigation.

AISC N690 provides the basis for justification of a higher stress limit by experimental investigation [test] for evaluation of the ACI 349 125% strength requirement



Coupler Weld Code Discussion

Two Separate Evaluations Performed

1. AISC N690 Load Combination Evaluation
 - Rebar assumed to be fully utilized for each load combination (i.e. $0.9f_y$)
 - Welds are evaluated using the SLC applicable to the load combination
 - All coupler welds are analyzed and found to be satisfactory
2. ACI 349 125% Specified Yield Strength of Rebar
 - Testing per AISC N690 Section Q1.22.2 is proposed to demonstrate that the weld strength exceeds 125% of the specified strength of the reinforcing bar by acceptable margin
 - Phase I: Testing the coupler, weld, reinforcement bar system
 - Phase II: Testing the coupler weld to failure
 - This approach has been reviewed and vetted by industry code experts
 - The testing confirms that the weld meets both AISC N690 and ACI 349 requirements

Phase I: Testing the Coupler, Weld & Reinforcement Bar System

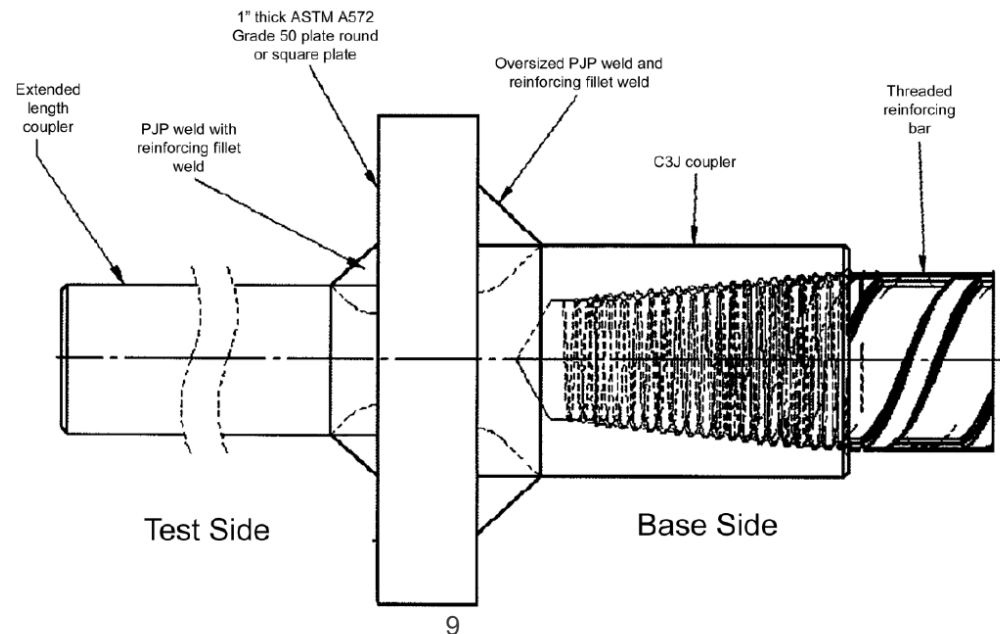
- Coupler system test performed for #7 through #11 welded coupler
- System tested to failure
 - 6 static, 3 cyclic tests
 - In all cases reinforcing bar or mechanical connection of bar fails
- 5% fractile strength calculated based on ACI 349-01 Appendix B approach
- The coupler system including weld strength exceeds 125% of the specified yield strength of the reinforcing bar and the specified ultimate strength of the reinforcing bar

The coupler system performs as intended with the failure occurring at the mechanical connection or rebar. The weld never fails.



Phase II: Testing Coupler Weld to Failure

- Tests to confirm the weld failure strength were also performed
- The tests were performed by manufacturing an extended length coupler of the same material used for the production couplers that could then be clamped directly in the tensile test machine
- The extended length couplers were welded to a base with a weld size made equal to or less than the size specified on the design drawings
- 10 samples each of #7 through #11 were tested statically to failure



Safety Margin

- The as found condition and the proposed change have adequate safety margin
- ACI 349 is met as the mechanical coupler system (including the weld) meets the 125% yield strength requirement and the weld is stronger than the rebar to ensure design is ductile
 - Weld is not the weak link in the design
 - The test results support a higher weld capacity and demonstrate that the margin in the design is adequate to satisfy the yield strength requirements in the CLB



A larger weld will not change the response of the structure in design basis or beyond design basis events

Shield Building Licensing Basis

- No Impact on Incorporated by Reference (IBR) document APP-GW-GLR-602 (AP1000 Shield Building Design Details for Selected Wall and RC/SC Connection)
- No impact on non-IBR document APP-1200-S3R-003 (Design Report for the Enhanced Shield Building)
- No impact on critical sections
- No impact on the seismic response of the nuclear island
- No impact on the probabilistic risk assessment
- No impact on Aircraft Impact Assessment (AIA)
- No impact on the Purdue testing

Shield Building Design

- Shield Building panels contain #7, #8, #9, #10, #11 C3J couplers at interface points with Auxiliary Building walls and roof
- As demonstrated by testing (discussed previously), weld capacity exceeds design requirements with adequate safety margin

Licensing Basis Impact

3.8.4.5.1 Supplemental Requirements for Concrete Structures

[Weldable coupler connections of reinforcing bar to structural steel shall develop 125% of the specified yield strength of the bar in accordance with ACI 349-01 Section 12.14.3.4. Qualification of the C2/C3J coupler welds is demonstrated as follows:

For reinforcing bar size #4, #5, and #6 the coupler connection weld adequacy is demonstrated by calculations in accordance with AISC N690-1994 requirements using a stress limit coefficient (SLC) of 1.6.

*For reinforcing bar size #7, #8, #9, #10, and #11, coupler connection weld adequacy is demonstrated through testing, as permitted by AISC N690-1994 Section Q1.22.2. According to ACI 349-01 Section 12.14.3.4.1, a minimum of six static and three cyclic qualification tests are performed for each reinforcing bar size on samples of the coupler reinforcing bar splice and weld system, retaining 5% fractile of the tension test results per ACI 349-01 Section B.4.2, and by testing the coupler weld to failure using ten representative sample weld configurations from each of the five reinforcing bar coupler sizes]**

Coupler System & Failure Testing Demonstrate Strength for Both Constructed and Future Welds. Prevents Two Designs Going Forward.



Questions

