Description of Work

Task 5.2: Topical Investigations on Joining and Inspection

Sub-Task 5.2.4 – Assess the reliability of available non-destructive evaluation methods to identify defects that jeopardizes the behavior of weld joints - Establish model UT procedures

Background

Please see the attached document "Overview of Topical Investigations on Joining and Inspection" for the technical background to this sub-task and the relationship between this sub-task and the other Joining and Inspection sub-tasks and the overall Phase 2 project.

Objectives of Sub-Task

Efforts will be undertaken in this sub-task to assess the reliability of available non-destructive evaluation methods to identify defects that jeopardizes the behavior of weld joints and to establish model UT procedures. The work will consist of evaluating ultrasonic test methodologies currently used for buildings and in industries other than the building construction industry to assess their applicability to typical building construction weldments. Promising techniques will be demonstrated on mock-up welded joints. Cost-benefit comparisons for the various methods based on achievable accuracy of reflector interpretation (relevant or not), sizing accuracy, inspection costs, and present day availability of equipment and services will be prepared. Most importantly, this work will establish a comprehensive series of model UT procedures - focused on complete joint Penetration (CJP) and partial joint penetration (PJP) weld geometries and sizes typically used in building construction - which will serve as baseline documents for the inspection personnel. Finally, the sub-contractor will also perform UT of specimens used in Sub-tasks 5.2.1, 5.2.2 and 5.2.3.

Description of Sub-task

Important welds used in building construction historically have been inspected using portable, manual, ultrasonic testing. The techniques used usually conform to the *AWS D1.1 Structural Welding Code - Steel* that delineates mandatory parameters for calibration and various weld thicknesses. The weld geometries best represented by these parameters are butt, tee, and corner joints with vee or bevel CJP groove welds.

The acceptance criteria in the AWS D1.1 code are based on amplitude comparison techniques. Recent editions of the code have required the use of "other techniques" when the reflector is determined to be planar, as the amplitude comparison techniques fail to adequately evaluate this type of flaw. Others include adding to UT procedures a provision for recognizing non-relevant indications from the weld geometry (AWS D1.1-96, Annex K),

This investigation will evaluate the different techniques now being used in other industries (i.e., offshore platforms, pressure vessels, and piping) for characterizing weld defects, determining the size of planar, cylindrical and spherical flaws, and determining geometric weld boundaries. Various techniques such as tip diffraction, time of flight, and feature recognition should be encompassed, as well as more recent developments in UT. Portable, manual techniques and equipment should be stressed, as opposed to highly automated systems.

The UT procedures and techniques incorporated in this series must address the welds common to contemporary building construction, e.g.,

1. Groove welds in tee joints, with and without backing bars
2. Groove welds between beam flanges and column flanges using standard pre-Northridge detailing practices
3. Groove welds between beam flanges and column flanges using standard post-Northridge detailing practices
4. Groove welds in skewed joints such us haunches and eccentrically braced frames
5. Groove welds in beam flanges reinforced with cover plates
6. Partial penetration groove welds as used in some column splices

The selected procedures must be written in an explicit 'how-to" instructional mode that is usable by an NDT technician who is experienced and proficient in the AWS D1.1 UT section. They must give explicit guidance on exactly how the equipment must be calibrated; how flaw indications are differentiated from non-relevant indications; and where planar and other flaw size must be used to support relevant/non-relevant discrimination. They should not duplicate the AWS D1.1 UT provisions, but may reference them where needed.

These procedures are intended for use with conventional pulse-echo and/or through-transmission techniques in common use. When conventional equipment and techniques are not effective or relevant, alternate methods should be cited. When and where other NDT methods or QC inspections are needed to support the UT procedure, these should be described.

To enable cost-benefit decisions to be made by users, a comparison of inspection costs (including time and equipment costs) and inspection availability will be included.

In addition, the subcontractor will perform UT inspection on all weld samples completed by others performing Subtasks 5.2.1, 5.2.2 and 5.2.3, and report the findings.

Task Description

To achieve the objectives of the sub-task, the subcontractor is expected to develop and submit for approval to the Project Director for Topical Investigations a detailed Sub-task Work Plan addressing the objectives of the sub-task. It is anticipated that this Work Plan will include, among others, the following items:

1. The contractor must attend necessary meetings during the period of the sub-contract (e.g., project kickoff and quarterly team meetings with the Project Director of Topical Investigations and the Technical Advisory Panel). The sub-contractor is expected to provide regular verbal and written reports to the Team leader for Joining and Inspection as well as to the Project Director for Topical investigations and be responsive to their requests related to the work.

2. Perform a literature search for information directly relevant to practical ultrasonic test applications regarding structural welds (or offshore/piping/pressure vessel welds where a direct correlation exists). Describe general industry practice and acceptance of various methods such as tip diffraction, time of flight, feature recognition, etc. Recent innovations and methods shall be sought out and considered.

3. Use the most promising methods and techniques on weld mock-ups of typical building construction joint designs, testing and demonstrating the effectiveness of the most promising techniques. Document the demonstration tests with normally collected UT data, plus weldment and flaw parameters. Describe for each weld configuration the specific elements of the test techniques - i.e., calibration, test equipment requirements, scanning patterns, possible non-relevant reflection sites, and other pertinent information. Evaluate the relative effectiveness of each procedure at detecting flaws specific to the weld joint under inspection. Define the defects that will not be detected by each procedure utilized.

   The plate and shape materials for the mock-ups will be provided by SAC and shipped to the subcontractor at no cost. Plates will be cut to near shape with bevels included. Plates will be in the thickness range of 1/2 to 2 inches. Welds will be approximately 6 inches long. Exact weld joint details as well as flaw types, sizes, locations, and orientations shall be decided in the first kick-off meeting. Welding and flaw implantation are the responsibility and cost of the subcontractor. However, care should be made that the inspectors evaluating the specimens are unaware of the nature and location of defects. Ten mock-up welds are envisioned:

i) One 1/2-inch thick plate welded to a 3/4-inch thick plate with a single bevel CJP groove weld in a tee-joint, without backing. (Represents small beam or stiffener to column connection.)

ii) One 1/2-inch thick plate welded to a 3/4-inch thick plate with a single bevel CJP groove weld in a tee-joint, with backing. (Represents small beam or stiffener to column connection.)

iii) One 1-1/2-inch thick plate welded to a 2-inch thick plate with a single bevel CJP groove weld in a tee-joint configuration, without backing. (Represents heavy beam or stiffener to column connection.)

iv) One 1-1 /2-inch thick plate welded to a 2-inch truck plate with single bevel CJP groove weld in a tee-joint configuration, with backing. (Represents heavy beam or stiffener to column connection.)

v) One 1-1/2-inch thick beam bottom flange welded to a 2-inch thick plate or column flange with a single bevel CJP groove weld in a tee-joint configuration, utilizing backing, run-off tabs and other details representative of pre-Northridge designs, with web interference and access hole present. (Represents beam to column connection**)**

vi) One 1-1/2-inch thick beam bottom flange section welded to a 2-inch thick plate, or column section with a single bevel CJP groove weld in a tee-joint configuration, with backing and run-off tabs removed, fillet reinforcement added, and with other details representative of post-Northridge designs, with web interference and access hole present. (Represents beam to column connection.)

vii) One 1-1/2-inch thick plate welded to another 1-1/2-inch thick plate at a 30^{o} skew angle**,** using a single bevel CJP joint, in a skewed tee-joint configuration. (Represents beam to column haunch connection at the beam end, or EBF bracing connection.)

viii) Two 3/4-inch thick plate, one on top of the other, welded to a single 2-inch thick plate using single bevel CJP groove welds, in a tee joint configuration. (Represents beam flange with cover plate to column connection.)

ix) Two 1-1/2-inch thick plates welded in a butt joint with a single bevel PJP groove weld. (Represents column splice.**)**

x) One 1-1/2-inch thick plate welded to 2-inch thick plate with a single or double bevel CJP groove weld, in a tee-joint configuration, with a simulated lamellar tear defect produced in the 2-inch thick plate. (Represents column lamellar tear.)

Report the methods used to control all welding parameters used in sample preparation. Include the QC methods and criteria used for base materials, electrodes, weld processes, inspections and testing. Document nonconformances found and their corrective action.

4. Report situations where modifications (either slight or substantial) to the joint design or welding operations could significantly enhance the effectiveness of U'I'.

5. Identify supplemental visual or other NDT methods that may better facilitate UT of the particular weld.

6. Report on the relative cost-effectiveness of each UT procedure.

7. Provide final written model UT procedures. All procedures will be prepared in conformance with format guidelines specified by SAC.

8. Using UT, inspect all specimens described in Subtasks 5.2.1, 5.2.2 and 5.2.3 and carefully map all indications. Welding will be performed by others.

9. Using UT, reinspect those loaded but unfailed test samples after loading to determine what changes, if any, occurred in the size and nature of existing weld discontinuities and the applicable UT data.

10. Provide regular progress reports and updates, at intervals to be defined during the kick-off meeting.

11. Provide a final written report that describes the results of the project. All reports will be prepared in conformance with format guidelines specified by SAC.

Deliverables

Subcontractor will have the following items as deliverables for this sub-task.

1. Revised and detailed work plan based on kick-off meeting discussions, including parameters of mock-up welds,

2. Summary of literature and copies of most relevant documents,

3. Description of general industry practice and recently developed and innovative techniques for UT.

4. Hold the sample mock-ups for two years. During this time, the mock-ups will be made available to researchers at no expenses. No more than three visits of approximately two weeks duration each are envisioned. On request of SAC, the subcontractor will ship mock-ups at SAC's expense to any destination.

5. Evidence of demonstrated effectiveness of the most promising techniques with all test data. Two complete sets of 35mm slides for use in presentations that describe the most promising equipment and techniques. Supplement the slides with two copies of a short video where slides are ineffective at conveying the relevant concepts.

6. Records of quality controls (including findings and corrections) used during the welding testing.

7. Model UT procedures for the common structural connections as listed in the Sub-task description. Include comments on the relative effectiveness of each procedure and defects that will not be detected. Indicate novel ways that the resultant UT findings can assist in the weld QC loop, including where modifications to the joint design or welding operations could significantly enhance the effectiveness of the UT. Provide the relative cost-effectiveness of each procedure. Identify supplemental visual or other NDT methods that may better facilitate UT of the particular weld.

8. Regular progress reports and updates.

9. Final report on the results of the project.

Task Management and Review

This subtask is supervised by James Malley, Project Director for Topical Investigations. The Joining and Inspection Technical Advisory Panel (TAP) will provide oversight and an advisory role on the conduct of the research and will review and evaluate reports and recommendations. The Team Leaders and selected members of the Materials and Fracture TAP and the Connection Performance TAP, as well as the Guideline Writers for In-Process Inspection, New Construction, and Repair will also review and evaluate this work. It is expected that the subcontractor/consultant selected for this task will be responsive to issues and concerns raised by the Project Director, TAP and other reviewers.

Target Audience

The work products of this task will be directly used by consultants and sub-contractors working on the SAC Phase 2 project. The general results and the interpretation of these results will be of particular interest to Topical Investigation Team Leaders for Materials and Fracture and Connection Performance, as well as Guideline Writers and other general users. The information developed in this task will be incorporated into the State-of-the-Art report on Joining and Inspection, and will form the basis for many of the Guidelines for in-process inspection and non-destructive evaluation to be developed in Task 9 of the project. The work products will also be of interest to practicing building inspectors, building officials, and developers and end-users of inspection and non-destructive testing equipment in the steel construction industry.