Description of Work

Task 5.2: Topical Investigations on Joining and Inspection

Sub-Task 5.2.5 – Synthesize available data to develop predictive model for weld performance that can be used to identify appropriate weld procedure(s) and process(es) considering intended behavior, joint configuration, material properties, and inspection 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 5.2.5:

Develop a Metallurgical/Mathematical model to predict the performance of FCAW-SS welded joints based on joint configuration, process parameters, base metal and consumables. Data obtained in other sub-tasks as well as in investigations outside of the Phase 2 project (welding literature) are to be synthesized, analyzed and interpreted to develop a correlating function between the behavior observed in the T-stub specimens, smaller butt-weld multipass test plates, and in basic material strength and fracture tests. This model is intended to be capable of predicting weld performance during seismic loading. The model will consider degree of restraint at the joint, joint configuration, base metal strength, weld metal strength, weld metal toughness, weld discontinuities, welding process parameters, strain rate and weld failure mode.

Description of Sub-task:

From the database generated for the simple welded joints constructed using the FCAW-SS process and tested in Sub-tasks 5.1.2, 5.2.1, 5.2.2, 5.2.3 and elsewhere, a theoretical/empirical model of joint behavior will be developed based on a description of its physical, material, metallurgical and defect characteristics, and loading intensity and rate. This data will be augmented by experimental and analytical information on full scale beam to column connections (Sub-tasks 5.3.1 and 7.02), as well as data obtained in Task 3 regarding the performance of actual buildings during past earthquakes. Information obtained outside of the project will also be utilized to develop this model, as appropriate. The confidence that can be placed in the resulting model will be evaluated.

The model should resemble or incorporate as many of the regions and factors for the conceptual representation in Fig. 3 as described in the companion document *Overview of Topical Investigations on Joining and Inspection*. The model is expected to be able to be incorporated into other finite element analysis packages that determine overall welded connection behavior. This model is also expected to determine the conditions in which fracture may occur and the respective failure mode and load. The model is to address issues associated with existing buildings as well as with new construction.

Areas where confidence in the results predicted in the model are high and low should be identified as should specific needs for additional information within current sub-task areas. If new lines of investigation are needed, these should be identified as well.

Scope of Sub-task

To achieve the objectives of the sub-task, the sub-contractor 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 and to the Project Director for Topical Investigations and be responsive to their requests related to the work.

2. The subcontractor is expected to work closely with those that perform Sub-tasks 5.1.2, 5.1.3, 5.2.1 through 5.2.4, and 5.3.1 as well as Task 7 . The investigator is expected to assist in establishing the testing methodologies of the other investigators to ensure maximum utility of the data obtained from the other test programs in the development of the predictive model for weldment performance.

3. Synthesize and evaluate the test results obtained from Sub-tasks 3.1, 5.1.2, 5.1.3, 5.2.1 through 5.2.4, and Task 7 as well as from the various analyses undertaken in Sub-task in 5.3.1 to identify a relation among the type of test conducted (i.e., connection, joint, plate or material tests), the strength and toughness of the metals in the base material and in the weld region, the welding electrode, procedure and parameters utilized, characteristics of defects present, loading rates, chemical or microstructural features of the weld or base material, and so on. These physical, material and metallurgical relations should focus on their influence on the failure location, mode and load (or deformation) for typical CJP welds in beam to column connections (Fig. 3) in new and existing steel moment-resisting frames.

4. Establish a theoretical-empirical model that numerically predicts failure points (failure location, mode and load/deformation) as a function of joint configuration, material properties, welding procedures and parameters, defect characteristics and so on. The model should be of a form suitable for inclusion in finite element models of joints or for simplified procedures for evaluating expected connection behavior. The confidence that can be placed in the model should be assessed by predicting behavior of welds in actual buildings or in beam to column tests (Task 7).

5. Design further weld experiments or finite element analyses, as necessary, to complete the database required for model development. Revise the model on the basis of these additional investigations. These activities are to be submitted for review by the Technical Advisory Panel, and approved by the Project Director for Topical Investigations, prior to initiating the investigations.

6. Submit regular progress reports and updates at intervals to be defined during organizational meetings. The investigator is expected to remain in continual communication with the other investigators working on welded joints within the Phase 2 project and help coordinate activities within these other sub-tasks so that the results support the development of the predictive model.

7. Prepare and revise a final report detailing the methodology used to assess the data obtained, the general nature of the results included in the study, the relationships identified (including the reliability of observations made in other sub-tasks reached on the basis of more limited data), the details of the theoretical/empirical predictive model developed, and the efforts made to assess the confidence that can be placed in the predictions. The report will be prepared according to format guidelines specified by SAC.

Deliverables

Subcontractor will submit the following items as deliverables:

1. Revised and detailed work plan based on discussions during project kick-off meeting.

2. Description of the data considered in this sub-task. This may be in a tabular or database format.

3. Metallurgical/theoretical interpretation of experimental data collected in Sub-tasks 5.1.2, 5.1.3, 5.2.1, 5.2.2 and 5.2.3.

4. Metallurgical/theoretical interpretation of the underlying phenomenon identified above as influencing the behavior of the welded joint.

5. Model that correlates the material, fracture (failure location and mode), welded plate, and T-stub welded joint results. Model that identifies the relation, if any, among process parameters and conditions, consumables, weld geometry, microstructure, defects and discontinuities, mechanical/fracture properties and loading conditions. Model should be suitable for inclusion in finite element or other types of analyses used for evaluation of new or existing welded steel moment resisting frame connections.

6. Regular progress reports and updates.

7. Final report on the results of the sub-task, including necessary revisions required by the Technical Advisory Panel and Project Director for Topical Investigations.

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 interest to Topical Investigation Team Leaders for Materials and Fracture and Connection Performance, as well as Guideline Writers and other general users. This task ties together all of the projects within Task 5.2 and therefore serves as the primary background for the State-of-the-Art Report on Joining and Inspection and the Guideline sections related to behavior of welded connections.