Description of Work

Topical Investigations on Materials and Fracture

Sub-Task 5.1.1 - Characterization of the Material Properties of Rolled Sections

Background: As part of Task 5.1, a series of investigations are being carried out to better characterize the material properties associated with structural steels, and the various factors that influence these properties. This information is critical to developing reliable procedures for the design of moment resisting steel connections. These investigations focus on a number of issues, including the following:

1. Characterization of material properties for rolled sections in the through-thickness (Z-axis) direction;
2. Characterization of material properties for rolled sections related to strength, elongation, toughness, hardness, etc.;
3. Correlation between mill test report (MTR) data and laboratory materials testing results;
4. The need for better understanding of variations in material properties across a cross section;
5. Identification of desired properties for structural steels in various applications;
6. Identification of loading and rate effects on joint performance;
7. Evaluation of the impacts of designs that incorporate multiple grades of steel as compared to single grade designs.

The manufacture of rolled steel shapes in the United States has undergone a significant change in the last ten years. Traditionally, rolled shapes were produced by integrated steel mills from steel manufactured in basic oxygen furnaces and cast into ingots. The ingots were then rolled into the structural shapes. The present practice of the major U.S. shape producers is to use electric furnace melted steel using scrap steel as the main ingredient. The melted steel is then continuously cast into near net shape blooms that reduce the amount of rolling required to produce the structural shape. The new shape producers are able to produce steel with tensile properties satisfying the requirements of ASTM A572 Grade 50 without the microalloys and with a lower carbon content than the integrated mills. Most of the structural shapes produced as ASTM A36 material by the new producers also meet the strength requirements of A572 Grade 50.

A survey of mill test reports indicates that a considerable portion of the grade 50 rolled shapes produced have a yield point reported on the MTR that is within 10 per cent of the required minimum value. Tests sections in connection tests sponsored by Phase 1 of the SAC Project and other investigations reported static flange yield strength levels as much as 25 per cent below the 50 ksi specified level. It is unclear whether these low yield strength values are due to differences in strain rate, differences between web and flange properties, or measuring yield point and yield strength values. Moreover, there appears to be no clear correlation between the MTR values and coupon test results from these recent laboratory investigations.

The reliable strength, elongation, toughness and other performance parameters of structural steels are not well known to practicing engineers. Most present design procedures utilize minimum specifications of material properties from standard ASTM specifications. However, the scatter in material property values found in practice makes it difficult to reliably predict the location and/or mode of failure in various joints. Further, the impending introduction of a new grade of steel into the U.S. market (single grade 50), as well as the inclusion of A913 steels, will likely mean that these future materials may not have properties that are as well understood as currently available materials, at least in the short term. Statistically valid characterization of these parameters are necessary for the development of reliable design procedures.

It is essential that the work in this task build upon current knowledge and not unnecessarily duplicate previous work. Thus, the activities undertaken in this task must be based on the assessment of current knowledge; including that undertaken as part of Task 4. The detailed work plan for this sub-task must account for and take advantage of other activities undertaken in the FEMA/SAC Phase 2 Project, and similar efforts within the steel industry. It is expected that the Subcontractor for this work will be in close liaison with AISC, SSPC and other steel industry representatives.

Objective: This task is intended as the initial effort to better characterize the basic material properties needed to develop connection and element design procedures. It is anticipated that additional funds will be provided by the steel industry to augment these subcontracts. Specific objectives of this project include the following:

1. To determine the relationship between mill test tension tests and the dynamic and static strength of rolled sections. Comparisons between laboratory test results from the web and flange of material adjacent to the mill test location and the results reported on the MTR. Along with a database of mill test results compiled by the producers, this information will be used to determine a statistically based relationship between the specified minimum strengths and the actual strength of the steel.

2. To characterize the complete stress-strain behavior of the steel that are presently being produced. This characterization is needed to develop recommended values for the strain at initiation of strain hardening, strain at tensile strength, and the effect of loading rate on the material performance.

3. To better understand the Charpy V Notch (CVN) toughness levels of various sections, and the potential for variation of this value across the cross section. A recent survey of the CVN toughness of rolled shapes indicates that the toughness is adequate for most applications. Independent testing of rolled shapes to confirm the previous survey results is warranted. CVN variations between different member sizes (heavy column sections vs. lighter columns and/or beams, e.g.) must also be better understood, especially in the core region at the web-flange juncture.

4. To investigate the properties of the rolled section in the region of the web to flange junction. Fractures initiating in the web in the vicinity of the flange to web fillet at the “k” dimension have recently been experienced on a number of projects. The material properties contributing to the extent and severity of this condition needs to be better understood.

5. To better understand the complete chemical composition of structural steels. Analysis shall not be limited to elements specified in ASTM requirements, but rather will include all those elements likely to be in the steel from the scrap materials used in the steel making

process.

Task Description: The steel for testing will be supplied by the shape producers. They have agreed to supply remnants of the section at the location where the mill tests specimens were taken. The remnants will include a portion of one flange and the full width of the other flange, and a portion of the web. The steels to be included in the testing are A36, A572 Grade 50 and A913, both Grade 50 and Grade 65. The producers anticipated to be included in the sample are Nucor-Yamato, Trade Arbed, Northwestern, British Steel, and Chaparral.

It is presently envisioned that this task will be conducted by a single subcontractor. The subcontractor will be responsible for coordinating with the steel producers, developing the testing requirements to be implemented, assessing and evaluating the results, and preparing the report of findings and recommendations for the project. In addition the subcontractor will be responsible for all of the physical testing to be performed, and the chemical analyses, as well as the cost of shipping costs to deliver the materials from the producers to the testing laboratory.

As part of this sub-task, the subcontractor will perform the following activities:

1. Prepare a detailed work plan for distribution and review by the Materials and Fracture TAP, the Team Leader and the SAC Project Management Committee. This work plan shall delineate the various tests to be performed (type, number, location, etc.) and the data to be developed and retrieved. Develop a detailed estimate of all tests to be performed based on finalized testing plan for review by the TAP and the SAC Project Director.This cohesive, clearly defined testing program will become the basis for the testing to be performed.
2. Coordinate proposed testing plan with the shape producers that will be providing materials for this work.
3. Attend a meeting with the Materials and Fracture TAP and representatives of the steel producers to finalize and approve the testing plan and the overall work plan.
4. Provide written documentation to verify that all equipment and procedures to be followed are in accordance with all pertinent ASTM specifications and any special requirements that may be established for this project. Included in this documentation will be provision for a tracking process to ensure that all materials received from various producers are uniquely and consistently identified, so that the correlation between mill and laboratory tests is clear for each piece of data.
5. Perform tension tests of both the web and flange from sections tested by the mill. These tension tests shall at least measure the yield point, static and dynamic yield strength, strain to strain hardening, dynamic and static tensile strength, and per cent elongation. The number and location of the tests will be defined in the testing plan, as will the sections to be tested. For material with a thickness less than 1-1/2 in., tests will be on 8 in. gage length full thickness plate type specimens. Smaller round 1/2 in. diameter specimens with a gage length of 2 in. shall be used for thicker material. The number of tests, number of producers and the shapes sampled shall be sufficient to develop a statistically valid basis for determining the relationship between values reported on the MTR and parameters measured in the laboratory tests, and to characterize the complete stress-strain diagram.
6. Perform CVN tests of the rolled shapes and sections identified in item 5 above, as defined in the testing plan. Longitudinal CVN properties of the flange (at the ASTM prescribed

location), and the core region shall be measured. This testing will include replicate tests of three specimens tested at 40F, 70F and 100F. Tests shall include similar shapes from different producers.

7. Perform hardness profile testing by method specified in the testing plan on shapes and sections selected from those identified in item 5 above.
8. Perform complete chemical analyses of materials as specified in the testing plan on shapes and sections selected from those identified in item 5 above.
9. Provide all compiled data in a format defined in the testing plan for inclusion in Appendices of the sub-task report.
10. Collect all available material property data from the steel industry that is needed to assist in the characterization efforts.
11. Communicate with Connection Performance Team Leader and TAP as required to coordinate efforts so that information that is needed to perform connection analyses and other topical investigations is provided in a timely manner.
12. Perform a complete, in-depth analysis and evaluation all data collected in the testing and obtained from the steel industry for development of project report. Data analysis and evaluation shall consider at least the following issues:
    a) Development of a relationship between MTR and laboratory test values for the range of shapes tested.
    b) Comparison of measured CVN values with recently published industry data.
    c) Evaluation of various web-flange juncture properties and their relationship with other locations of the cross section.
    d) Evaluation of the stress-strain characteristics obtained from various tests. Development of characteristic stress-strain curve.
    e) Develop other information as requested by Connection Performance Team Leader and TAP that can be generated from the collected data.
13. Prepare project report draft for submittal to and review by the Materials and Fracture TAP, the SAC Project Director, and Team Leader for Connection Performance.
14. Attend Materials and Fracture TAP meeting(s) to present results of the draft report and receive review comments and suggestions.
15. Prepare final report for submittal to SAC.

Task Management and Review: This sub-task is supervised by James Malley, Project Director for Topical Investigations. The sub-contractor will be part of the Topical Investigation Team on Materials and Fracture and participate in its meetings during the duration of the sub-task. In addition, the Technical Advisory Panel (TAP) for Connection Performance will provide review of the specific work activities recommended as well as on all reports and communications. The Team Leaders for Joining and Inspection and Connection Performance will also review the content of this work.

The sub-contractor shall be responsible for regularly reporting progress and difficulties to the

Team Leader for Materials and Fracture and the Project Director for Topical Investigations. It is expected that the sub-contractor will be responsive to issues and concerns raised by the Team Leader, Project Director, TAP and other reviewers.

Target Audience: The work products of this sub-task will be directly used by other consultants and subcontractors working on the FEMA/SAC Phase 2 project. The results will help provide tools and assessments that can be used during the remainder of the project.

The results of these characterizations of material properties will be used by investigators conducting connection experiments and those performing connection performance analyses. It is desirable that the results of these tests be reported in a manner consistent with methods used to report analytical estimates of connection capacity and demand. Thus, the Topical Investigation Teams on Connection Performance and Joining and Inspection will have keen interest in reviewing and using the results of this sub-task.

It is expected that the results of this sub-task will also be of great interest to the general professional and research community, as well as the steel industry.