I – Problem Statement Title (04-EQ096)

Determining the Effects of Low Cycle Fatigue on the Seismic Performance of Rebar and Couplers for Critical Structural Members

II – Research Problem Statement

Question: Are current qualification criteria, which are based on monotonic (single pull) testing, adequate to ensure the expected performance of rebar and couplers under seismic loading with multiple cycles of full inelastic stress reversal (low-cycle fatigue)?

The research is to investigate and determine the longitudinal reinforcement low cycle fatigue capacity of bar and couplers (#5 thru #18) subjected to large inelastic strains up to 6%. The parameters under investigation shall address at a minimum; the test strain, the frequency of imposed cycles including tension and compression loading, and the unbraced length of the tested rebar necessary to replicate the plastic hinging mechanism. In addition, due to the lack of cyclic testing data at seismic strain rates, the seismic design criteria manual (SDC) defines the "ultimate coupler" as one that will develop the full strain energy absorption capacity of a reinforcing bar under a single pull test. Preliminary undocumented tests at Translab indicates that there is a good possibility that some of the approved couplers may not qualify for the "ultimate coupler" class had there been a low-cycle fatigue requirement.

III – Objective

The research objective is to gain identification of fundamental properties of large diameter rebar and couplers used in bridge columns. The research will aid in developing much-needed cyclic testing criteria for longitudinal reinforcing steel and couplers in the plastic hinge zone and to update the SDC accordingly. This will enhance the assurance that what is being installed in critical structural members is performing as expected by engineers and as claimed by manufacturers

IV – Background

Current codes and specifications on the design of earthquake resistant bridge columns include provisions for the amount of transverse reinforcement needed to provide longitudinal bar restraint in plastic hinge zones. These provisions are based on testing done for scaled columns containing small diameter bar (i.e. less than #8). Furthermore, the provisions are mandated regardless of the severity of the seismic hazard. The issue of rebar scaling and its effect on low cycle fatigue has been difficult to address because of physical testing obstacles that have delayed progress in this area. Also preliminary undocumented trial tests at Translab in the years 1995-1996 indicated that some couplers which develop the full capacity of a reinforcing bar (#5 & #6) under monotonic loading

were failing during the second loading cycle under cyclic testing at plastic strains with stress reversal. While, reinforcing bar test samples were failing after 10 to 20 cycles. After examination of the failed sample, it was found that during the manufacturing process of this particular coupler the reinforcing bar end was being gripped very tight in the course of forging the threads at the bar's end which caused hardening of the material. Fortunately Translab did not approve this coupler at the time. It failed the thread tolerance test requirement. However there were other couplers that outperformed the reinforcing bar while the potential fatigue critical manufacturing limitations remained uninvestigated.

V – Statement of Urgency and Benefits

A. Support of the Departments Mission/Goals:

(Improving Mobility: Safety and Reliability) Perhaps the most important factor of urgency is the safety aspects of this research since it will better ensure that the critical structural elements have been tested in a seismic replicated environment and will perform as expected and designed for. As a scenario an important bridge near fault, in a major seismic event (30 sec of shaking at 2-cycles per second i.e. 60 cycles of which 10 cycles could be of maximum amplitude). Ensuring that the main reinforcement of critical structural members (ex. columns) are adequate to withstand 10 cycles of heavy shaking (low-cycle fatigue where rebar and couplers reaching stresses causing +/-4% strain) becomes extremely urgent when we know from preliminary tests that some couplers and rebars could fail after only one or few cycles at these strains. Also this research will help develop a better assessment of the level of damage caused to a bridge after a major seismic event and how this affects traffic carrying capacity.

B. Return on Investment:

This research is critical in going forward with the practice of designing bridges in areas of high seismic hazard. Based on Caltrans GIS system, more than 50% of the bridges in California may be subjected to high levels of seismic ground motion potentially inducing low cycle rebar fatigue. Add to that the fact that at least four fields will benefit from this research, including structure design, maintenance, research, and testing.

In addition to providing a more reliable design and seismic performance parameter, it will eliminate the need to perform certain expensive large-scale tests on structural members to study the plastic hinging mechanism. This research will enhance our quality assurance of critical structural elements, which will prevent possible catastrophic failure of bridges saving millions of dollars. Also the gained information may eliminate the need to replace certain damaged bridges after an earthquake by being able to better quantify the damage to it's critical members thus resulting in potential savings in the $10 Millions and perhaps more.

VI– Related Research

The inventory of bridge components testing has been conducted with scaled-down specimens containing small diameter rebars. A fundamental need exists in filling this gap

that is described in item IV. No recent research found.

VII – Deployment Potential

This research will provide engineers with real time data on the earthquake resistance capacity of ductile structural members. The resulting data are also invaluable in helping engineers estimate the cumulative fatigue damage caused to the reinforcement due to the performance in multiple earthquakes, even if little or no visible damage can be detected. Hence determine when the fatigue resistance capacity of the reinforcement has been depleted. On the other hand, the data on couplers will provide the ability to compare and qualify couplers according to their performance in real time cyclic testing.