SFSI TEST STRUCTURE AT GVDA:

CONSTRUCTION REPORT

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INTRODUCTION

This report documents construction of the Soil-Foundation-Structure Interaction (SFSI) test structure at the Garner Valley Digital Array (GVDA), a part of NEES@UCSB. This structure and its instrumentation were designed and constructed in 2003 and 2004 by a team from USC led by Robert Nigbor.

Figure 1 below shows the original GVDA site with a computer rendering of the proposed SFSI test structure. Figure 2 shows the site after construction on the August 19, 2004 Grand Opening.

This brief report contains background on the planning and design, a description of the construction process, and a discussion of costs for both the initial structure and for future replacement structures.

Figure1. GVDA site in 2003 and rendering of the SFSI test structure

Figure2. GVDA SFSI test structure at the 8/19/2004 Grand Opening
From left to right: Les Youd (BYU), John Wallace (UCLA), Jamie Steidl (UCSB), Marta Brown (Brown Foundation), Vilas Mujumdar (NSF), Ken Stokoe (UTA)

PLANNING & DESIGN

Planning for the SFSI test structure actually began during the NEES Phase 2 proposal effort in early 2002. The proposal team was led by PI Les Youd of BYU and included Jamie Steidl of UCSB and Robert Nigbor of USC as co-PI's. After successfully gaining one of the five awards for Phase 2 NEES Equipment Sites, the overall NEES@BYU project began in October 2002. A subaward was given to USC for the SFSI test structure and related effort.

The SFSI test structure was the responsibility of co-PI Nigbor and his team at USC. Partners in the work were Associated Engineers for construction (led by Saeed Banaie) and Digitexx Data Systems for instrumentation (led by Dan Radulescu). Ali Asghari and Navid Nastar were graduate students at USC involved throughout the construction. Les Youd and his BYU team contributed to the site investigations, and Jamie Steidl and his UCSB team contributed to the construction effort. Many others assisted with the various stages of design and construction.

The general concept for the SFSI test structure at GVDA was to have a medium-scale reconfigurable steel-frame structure founded on a rigid, massive concrete slab on grade. The superstructure should be of a size appropriate for testing on one of the NEES shake tables. Provisions should be made for mounting shakers on the roof for active experiments to complement passive earthquake monitoring.

General design goals for the GVDA SFSI Test Structure were as follows:

- Simple, spread footing at grade
- 700-1000 psf footing load to insure high soil stresses
- ~50% of mass in foundation to insure significant SFSI
- Superstructure size appropriate for NEES shake tables (4mx4m, 50 ton maxima)
- Steel moment frame to allow flexibility
- Configurable bracing system to allow stiffness/damping modification
- Strong RC rigid roof slab to allow mass addition and shaker mounting
- 7-10 Hz fixed-base natural frequency of superstructure (can be adjusted from ~5-15Hz with stiffness & mass)
- Cladding with flexible connections
- Instrumentation with basic sensors to describe its response, including accelerometers, rotational velocity sensors, strain gauges, pressure cells, and uplift displacement
- A data acquisition system with real-time remote data capability
- A small shaker (100 lb force) installed on the underside of the roof slab to allow active, low-strain modal testing and experimentation

The SFSI test structure design specifications are detailed in a separate document entitled "SFSI Test Structure at GVDA: Preliminary Design Report" dated Feb. 19, 2003. This preliminary design was created from October 2002 – January 2003 by the USC team. It was approved by the project's External Advisory Board in February 2003.

Upon approval of the general design, the engineering firm Associated Engineers was contracted to create detailed design drawings and then to construct the SFSI test structure. These detailed design drawings are included in Appendix A; high-resolution AutoCAD versions are available upon request. A final "As-Built" drawing is included; this drawing provided the final dimensions and configuration.

CONSTRUCTION

TIMELINE

Table 1 below provides a timeline for the design and construction of the SFSI test structure.

Table1. GVDA SFSI Test Structure Construction Timeline

Dates	Activity
Feb. 2003	• Final design approval by External Advisory Board
Mar. 2003	• Permission for Construction by Lake Hemet Municipal Water District
Apr. 2003	• Order instrumentation from Digitexx • CPT measurements, select exact location for structure
Sep. 2003	• Receive instrumentation • Begin testing of instrumentation
Feb. 2004	• Complete instrumentation test & calibration
Mar. 2004	• Install data acquisition system in GVDA instrumentation bldg. • Grade and prepare SFSI structure site • Drill boreholes under and around SFSI structure
Apr. 2004	• Begin construction • Procure steel components • Prepare soil pressure sensors
May 2004	• Build fence around site • Install soil pressure sensors • Form and pour bottom slab
Jun. 2004	• Erect columns • Form top slab
Jul. 2004	• Pour top slab • Begin sensor installation
Aug. 2004	• Remove forms and clean up site • Complete sensor installation • Complete cable installation, test instrumentation system
Aug. 19	• Grand opening ceremony • Measurements of forced vibration from UTA T-Rex shaker truck
Sep. 2004	• Install small shaker system • Final system tests • Leave system in triggered monitoring mode

FINAL PHOTOGRAPHS

Figures 3-10 are photographs of the completed SFSI test structure.

Figure3. GVDA entrance, showing gate, fence, SFSI structure, and instrumentation building

Figure4. Completed SFSI test structure from SW

Figure5. SFSI test structure, view from northwest

Figure6.   Bottom slab NW corner, showing displacement sensor

Figure7.   Bottom slab corner with vertical accelerometer, displacement, and soil pressure instrumentation

Figure8. Top slab sensor enclosures

Figure9. Main cable junction box

Figure10. Data acquisition cabinet in monitoring building

CONSTRUCTION COST

The total amount of the USC subaward for the SFSI test structure design, construction, and documentation was about $500k. Of this amount, $79k was a direct subcontract to Associated Engineers for design-build services for the structure itself. About $250k was spent on the instrumentation and shaker systems. The remainder went to design, construction, and management labor by the USC team.

It is intended that the SFSI structure be destructively tested by researchers looking at limit behavior of the soil and the structure. Once this is done, the structure will have to be repaired or replaced as part of the research costs. The connections of the columns to top and bottom slabs are bolted to facilitate replacement, and both slabs have imbedded lifting hardware sufficient to allow the slabs to be moved by a large (20-ton minimum) crane.

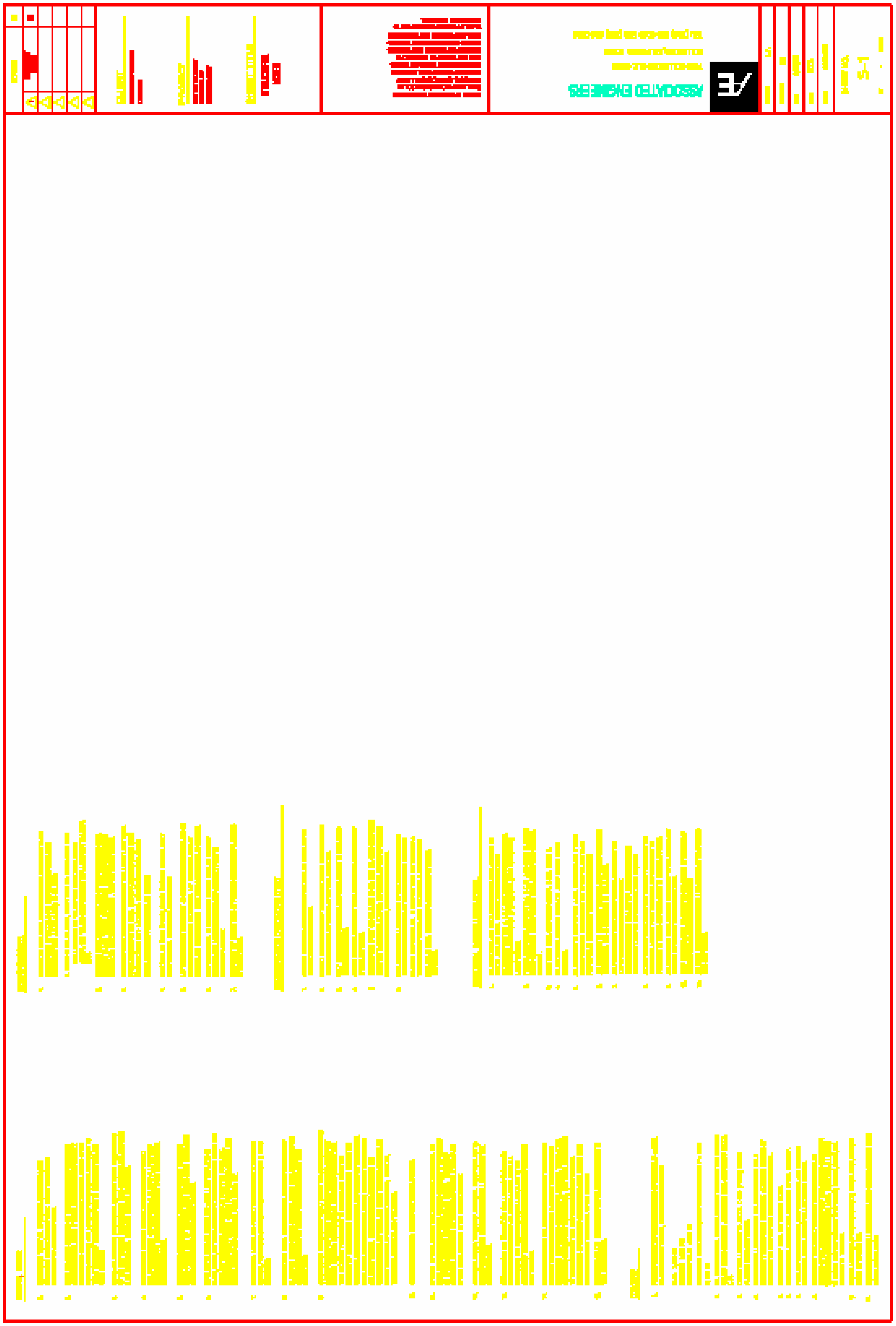
The most likely scenario is that the soil has failed under the bottom slab and the structure needs to be moved to a new undisturbed location a few meters away. In this case, the following work must be done:

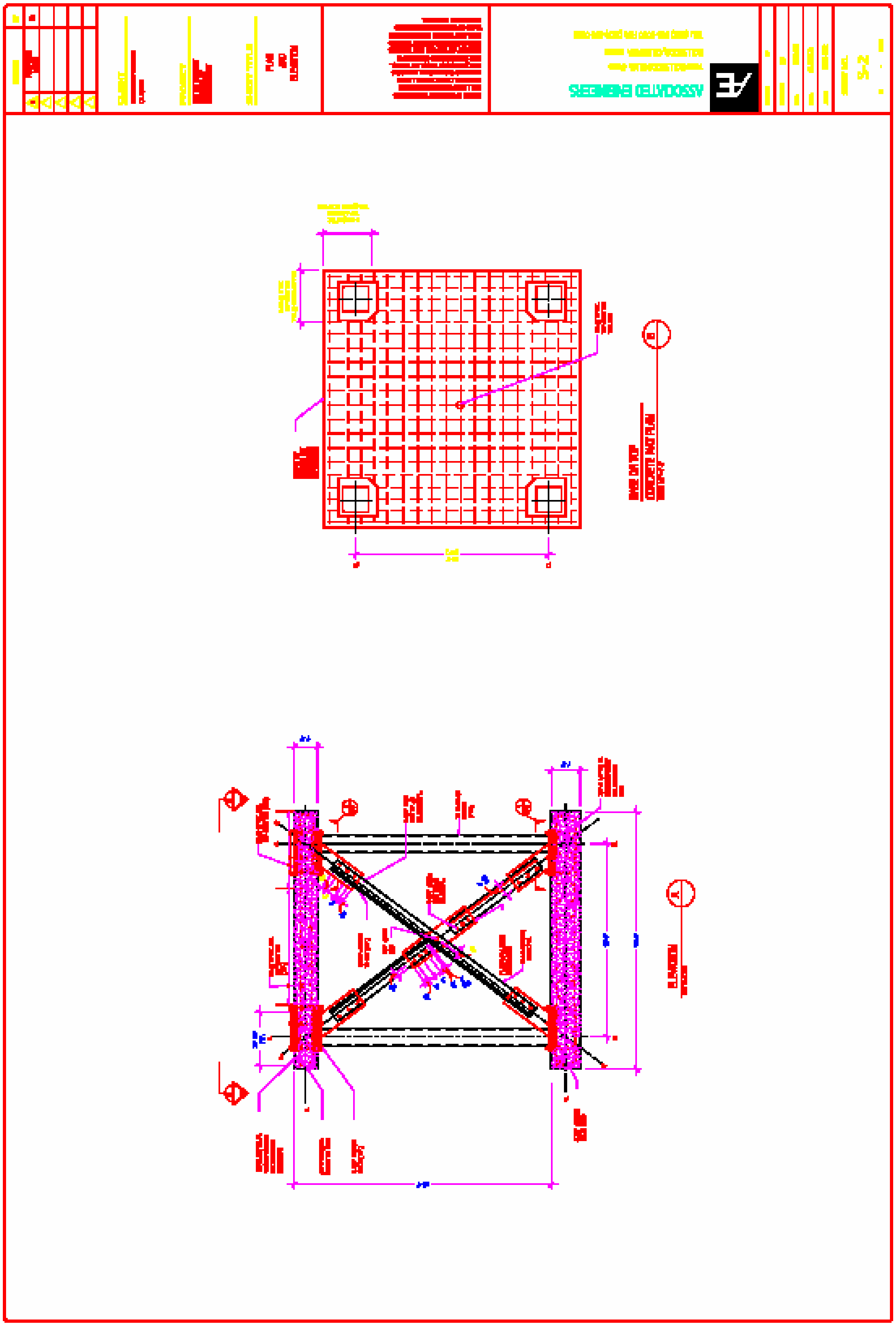
- Prepare new pad
- Drill new boreholes (if required)
- Remove sensors and cables
- Remove top slab
- Remove columns
- Move bottom slab to new site (care with soil pressure sensors and boreholes)
- Install columns
- Install top slab
- Install sensors

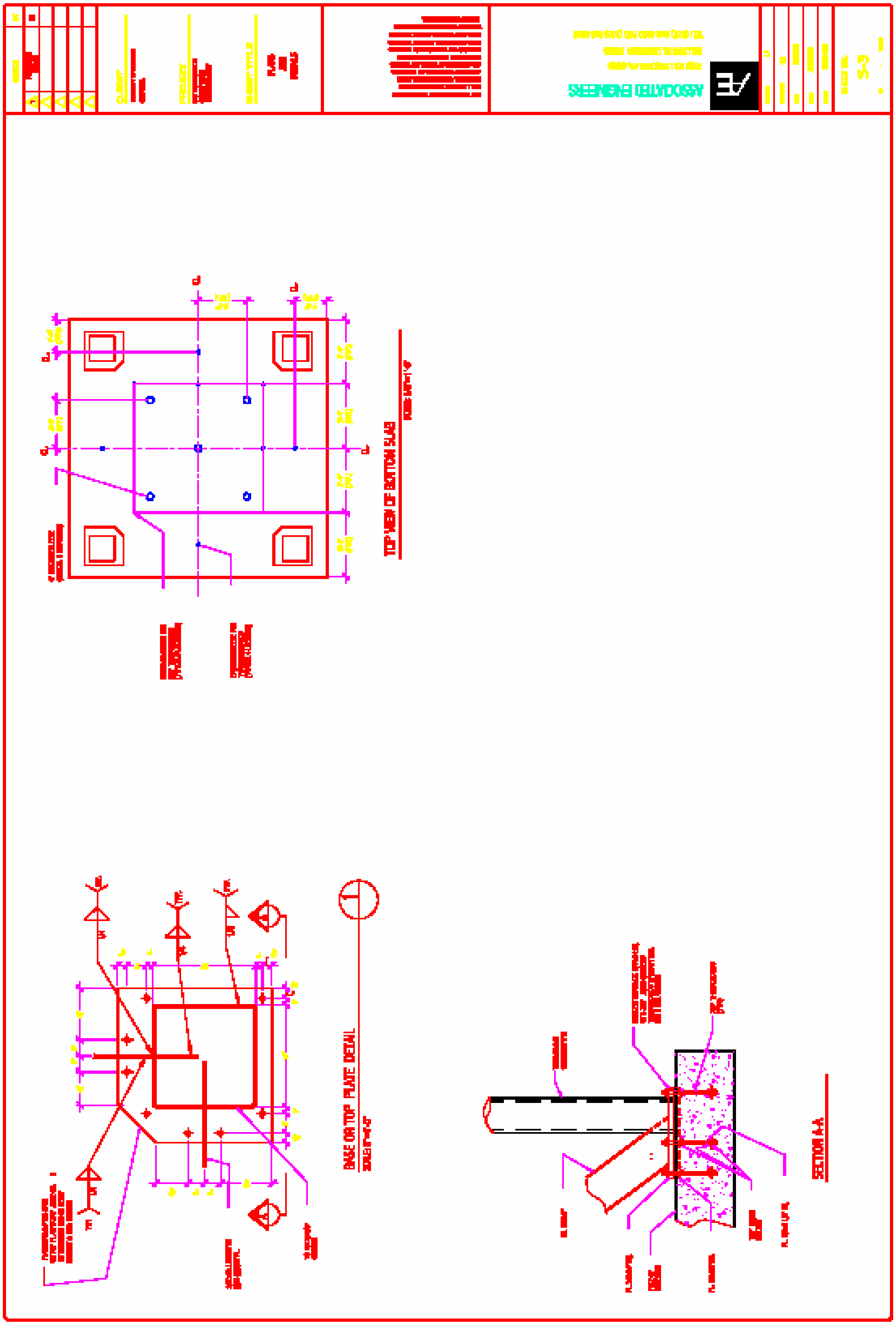
The estimated cost for this effort is $50-70k, depending upon the need for boreholes under the new slab location. It may be more desirable to pour a new bottom slab and move only the superstructure, in which case the cost would be slightly higher.

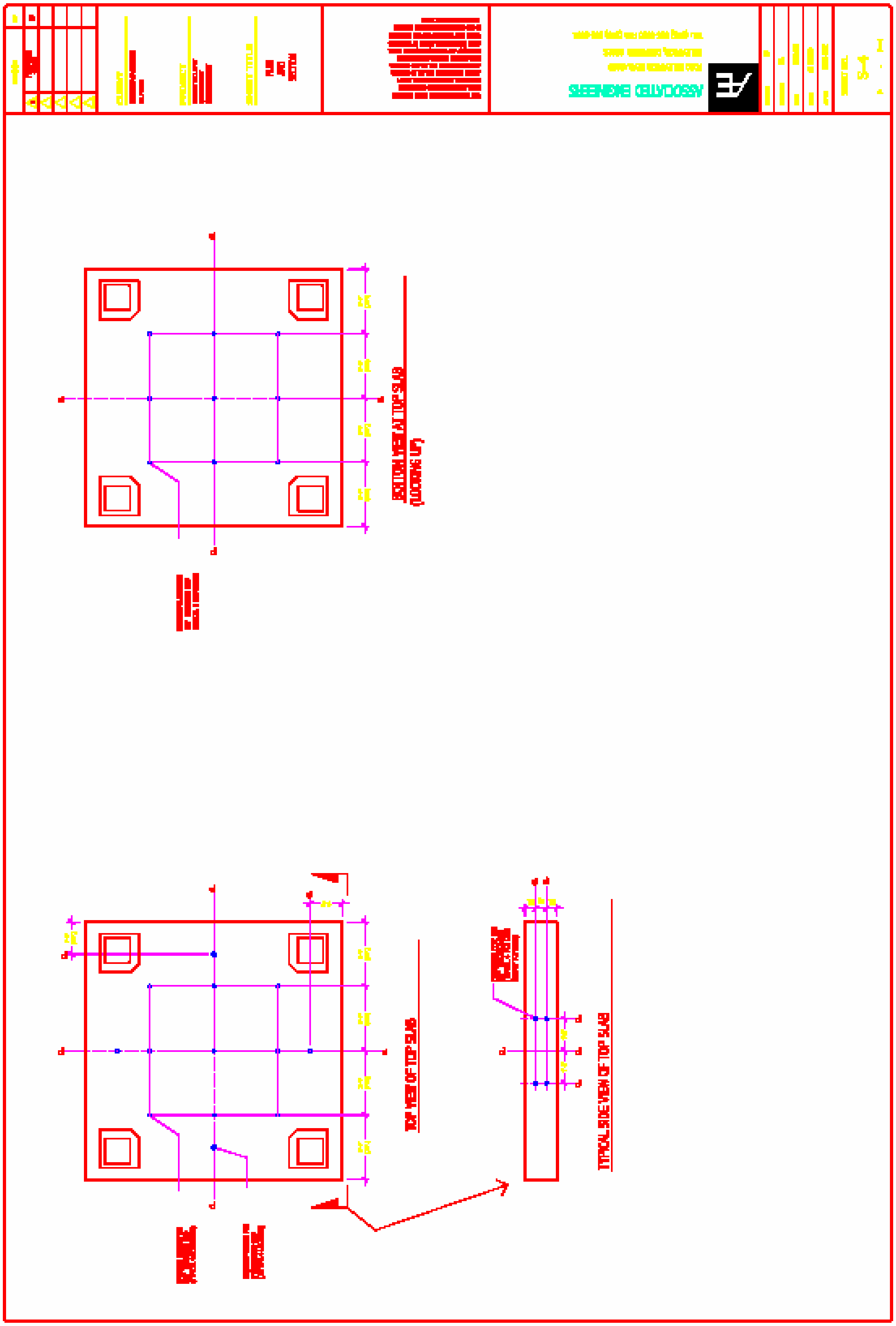
The NEES@UCSB site operations staff should be consulted whenever planning a research project that may damage the SFSI test structure or the soil under it, so that a more exact cost estimate can be provided for the planned research.

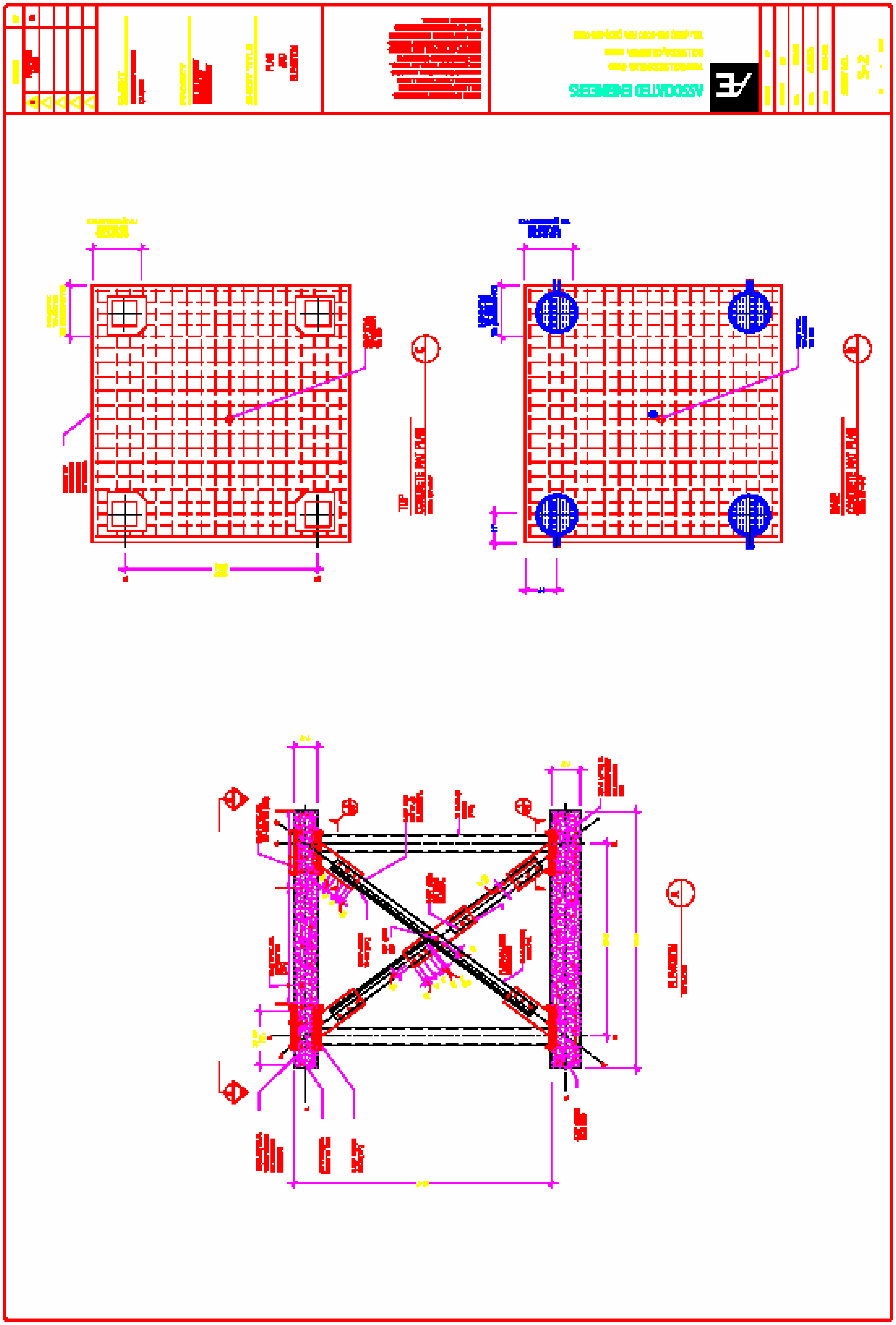
APPENDIX A: SFSI DESIGN DRAWINGS



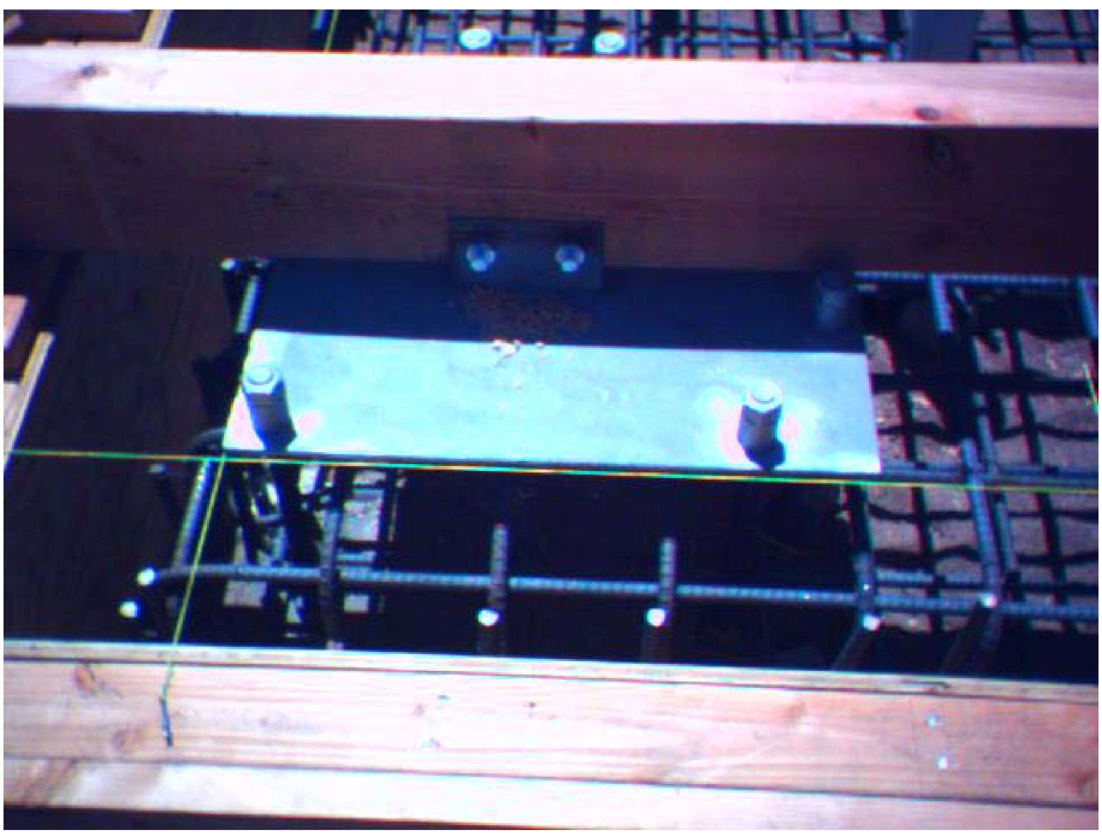



TOP VIEW OF BOTTOM SLAB
BASE OR TOP PLATE DETAIL
SECTION A-A


ASSOCIATED ENGINEERS
BOTTOM VIEW AT TOP SLAB
(LOOKING UP)
TOP VIEW OF TOP SLAB
TYPICAL SIDE VIEW OF TOP SLAB



APPENDIX B: CONSTRUCTION PHOTOGRAPHS

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