Lymon C. Reese & Associates
LCR&A Consulting Services - Strain Bars

The company has a long history of performance of tests of piles and pile groups under a variety of loadings. This document relates to the testing of single piles under axial load, either by top or bottom loading. While services can be offered for the testing of un-instrumented piles, the emphasis in the presentation is on the testing of instrumented piles with Strain Bars.

For all load tests, LCR&A can provide a highly qualified, experienced engineer for the test and other support personnel as needed. Personnel for assisting the engineer from LCR&A often are more economically provided by the Owner, Engineer, or Contractor.

Description and Use of Strain Bars

Strain Bars, instruments produced by LCR&A, are installed at various depths in a drilled shaft to measure levels of deformation. Two types of strain bars are available, Electrical-Resistance Strain Bars and Optical Strain Bars. Strain readings obtained from the Strain Bars and values of the modulus of elasticity, obtained from tests of concrete specimens, are used during a load test to compute the load that actually exists at each depth in the shaft. These data can be interpreted to obtain the amount of load that is transferred from the drilled shaft to the neighboring soil in skin friction and end bearing. If Strain Bars are closely spaced along the drilled shaft, analysis of the family of curves showing distribution of load as a function of depth will yield the valuable load-transfer curves, *t-z* for skin friction and *q-w* for end bearing.

Fig.1 Installation of instrumented cage

Figure 1 shows the installation of an instrumented rebar cage into a drilled hole. If desirable, LCR&A can provide specifications on construction of drilled shafts to ensure construction of high quality, essential in a test shaft.

In general, a Strain Bar consists of an all-thread steel bar of ½” OD, instrumented at a machined section near its mid-length with either electrical-resistance strain gauges or optical strain gauges. Strain Bars are installed in multiple groups (2 or 3) at each depth of the shaft, in order to provide redundancy of readings and to account for the effect of load eccentricity. The all-thread bars are approximately 2.5-ft in length. The threads in the bars allow for better bonding to the concrete mix.

Fig. 2 Electrical-Resistance Strain Bars

Electrical-Resistance Strain Bars

Electrical Strain Bars are normally used due to their cost, availability, good stability, and ease of measuring. Important techniques have been developed to insulate the electrical-resistance strain gauges against the intrusion of moisture and to provide protection against minor physical damage that could arise during construction. Leadwires are selected appropriately to eliminate electromagnetic interference, to resist direct physical damage, and to resist moisture intrusion. Figure 2 shows a set of Electrical-Resistance Strain Bars with attached lead-wires.

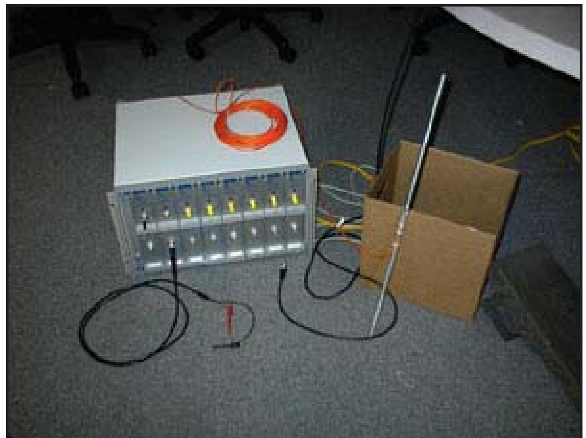

Fig. 3 Optical Strain Bars

Optical Strain Bars

Optical Strain Bars are similar to electrical-resistance strain bars in size and dimension. However, the optical sensors, unlike the electrical-resistance gauges, are mounted to the all-thread steel bars. A sensor can pick up signals from the variation of strains in millisecond intervals generated by dynamic loading. Optical signals have to be generated in order to perform reading of the optical strain bars. A 1000-Hz signal conditioner is used for that purpose, capable of registering 8 simultaneous channels of Optical Strain Bars at 1000 Hz. Optical strain bars are perfectly suited for measuring the strains under dynamic loads.

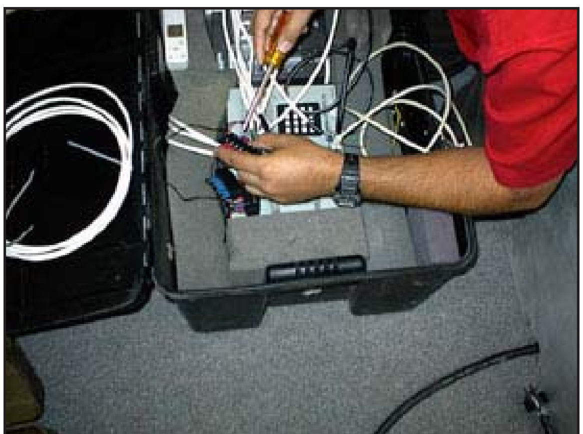

Fig. 4 Data Aquisition System

Data Aquisition System

The leadwires extend from each Strain Bar extend an appropriate distance away from the test shaft, for safety, where they connect to an automated data aquisition system (ADAS) that is in turn connected to a notebook computer. The Strain Bars, leadwires, completion bridges, ADAS, and notebook computer are all available from LCR&A. The ADAS is programmed to read instruments at set intervals, usually every 10 seconds during loading but with a longer interval while maintaining loads. Readings of load cells will also be registered by the ADAS at each reading interval. LCR&A can provide load cells that have been recently calibrated. The Contractor will provide the reaction system with a hydraulic ram. A calibration chart with the hydraulic ram is used during testing for the application of the selected load.

Testing Conditions

The exact location of the test site is to be defined between interested parties according to construction procedures and available soil investigations. The test layout will have the same configuration used in typical axially-loaded tests for the placement of the reaction system, reference beams, and the loading system.

Each strain bar will be calibrated in the laboratory before shipping. Each individual strain bar was positioned and clamped to the rebar cage with the axis of the bar parallel to the axis of the test pile. Two or three strain bars are normally installed at each level so that readings can be averaged. Because it is not possible to place the strain bar at the central axis of a pile, strain bars spaced at equal distance around the circumference of a pile will allow the effects of eccentricity to be defeated and eliminated. These bars (along with their fixed lengths of leadwires) and other bar extensions without instrumentations will be provided by LCR&A, assembled on site, and tied to the longitudinal bars after rebar cage is assembled.

Fig. 5 Strain Bars installed on rebar cage

A Campbell Scientific Model 23X automated data acquisition system (ADAS) can be used to scan all readings of displacement and applied load. The ADAS will be programmed to scan data every 10 seconds during loading/unloading. Data will be stored in temporary memory and retrieved in every load stage with a notebook computer. Appropriate plots of load and displacements will be available immediately for evaluation and to compare with predicted values.

Two electrical strain bars may be placed near the top of each test shaft, where no axial load is being transmitted to the soil, to allow for a calibration curve to be developed experimentally which may help to convert strain into axial load in the column.

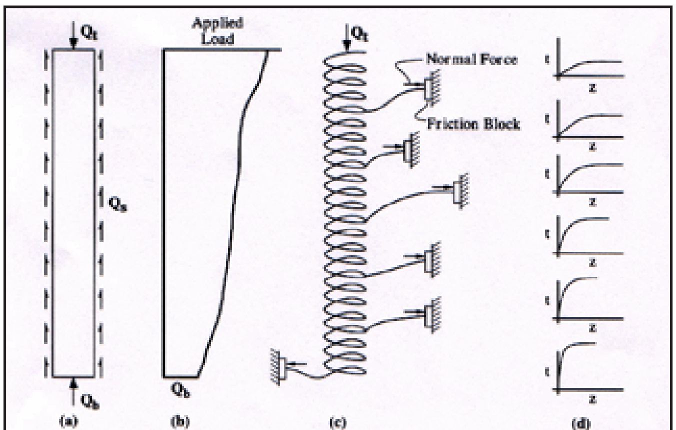

Fig. 6 *t-z* model for pile analysis

Testing Equipment

The following equipment will be necessary during testing:

a A pump operator will be desired for the duration of the test.
b Vehicular access to test site is desired in order to maintain electronic instruments inside a vehicle, plus to obtain backup power for computer from 12V receptacle in vehicle. Otherwise, a small work table, plus a tent or some other method of protection from direct sunlight and rain may be necessary.
c Lights and small generator may also be necessary during testing.

Post-test Report

A complete test report should include the following items:

a Short textual introduction.
b Charts of axial load vs settlement showing raw measured values from each displacement sensor.
c Charts of axial load vs settlement showing averaged values of all working displacement sensors.

d Charts of axial load vs settlement before and after creep, if relevant.
e Charts of comparison between load readings from electronic load cell and converted pressure gauge readings.
f Charts of readings from digital strain bars embedded in the drilled shafts (only strain readings, conversion to stress depend on moduli of elasticity of concrete samples and on optional data-interpretation contract with LCR&A)
g Electronic spreadsheet of measurement tables that were used for preparing all charts.
h Electronic spreadsheet of raw measurements.
i Printout of most recent calibration curves of all electronic instruments used during the test.
j Final electronic files.

Data Reduction and Presentation

All measurements logged during testing operations need to be reduced eliminating accidental readings, electrical noise or other erroneous measurements. Results will be presented with graphical readings of strain for each instrumented depth, and using load and settlement from instrumentation on top of the test column.

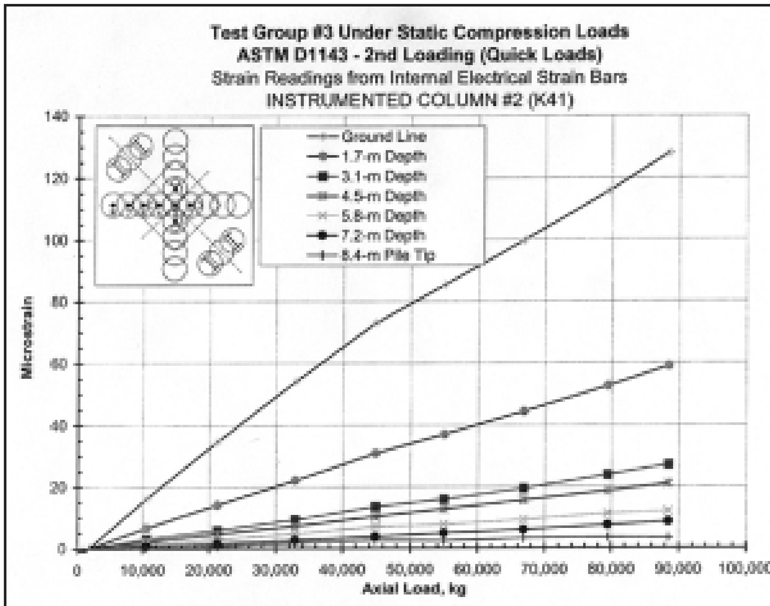

Fig. 6 Averaged Strain Readings from Electrical Strain Bars

Data Interpretation and Complete Test Reporting

If desirable, LCR&A can provide the engineering effort necessary to finalize load-test interpretation, including the following:

a Charting of load distribution curves based on measurements from digital strain bars
b Interpretation of load-settlement curves according to soil profile from geotechnical investigations at site
c Interpretation of load-transfer curves according to soil profile from geotechnical investigations at site
d Preparation of report booklet, including drawings, charts, and measurements