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Instruction Manual

Model 4370

Concrete Stressmeter

(Doc Rev G, 05/1/19)

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1. INTRODUCTION

The Geokon Model 4370 Concrete Stressmeter is designed to measure stresses in concrete. Conventional ways of doing this suffer from some drawbacks: for instance, strain gages can measure strains but the conversion of strains to stress is made difficult because of changing modulus with time, shrinking and swelling due to varying moisture content, and creep under sustained loads. Most of these problems can be overcome using hydraulic Flat Jack type stress cells; however, these cells are subject to a strong temperature dependence, which can also cause de-coupling of the cell from the surrounding concrete requiring a means of re-inflating the cells after the initial concrete curing period.

The Model 4370 Concrete Stressmeter is designed to overcome these problems by, in effect, making a stressmeter out of concrete so that it will have the same properties of shrinkage/swelling, modulus variation, temperature dependence, and creep potential, as the surrounding concrete.

2. OPERATING PRINCIPLE

The Model 4370 Concrete Stressmeter is shown in Figure 1.

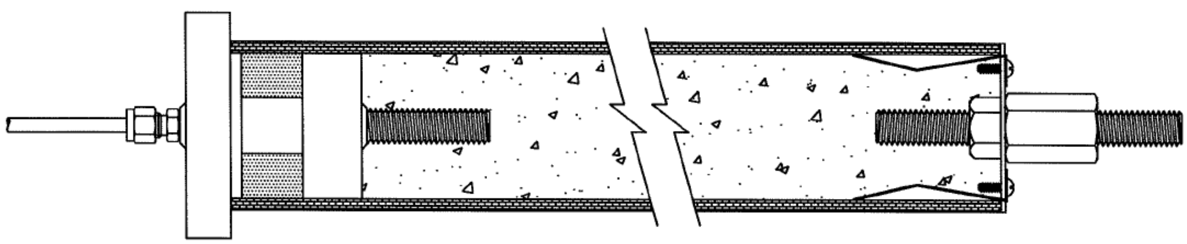

Figure 1 - The Model 4370 Concrete Stressmeter.

In essence, the stressmeter comprises a short vibrating wire load cell, in series with an 18-inch-long cylinder of concrete. This concrete cylinder has the same properties as the surrounding concrete but is de-bonded from it by means of a smooth-walled, porous plastic tube and is coupled at its ends to the surrounding concrete by means of a flange at one end and a piece of all-thread rod at the other. The vibrating wire load cell measures the load imposed on the inner concrete cylinder by stresses in the surrounding concrete. This load, when divided by the cross-sectional area of the inner cylinder, gives the stress in the surrounding concrete. Variations of moisture content in the surrounding concrete are felt also by the inner concrete so that shrinkage and swelling are the same both inside the cell and out, leading to no net change in the load cell readout. (This is not strictly true due to the short length of the metal load cell portion, which behaves differently, but the effect is kept small by the large difference in the relative lengths of the concrete cylinder versus the length of the load cell).

A thermistor is included inside the cell for the measurement of temperatures.

3. INSTALLATION

The Stressmeter is first wrapped in A Tyvec type material for additional de-bonding power. The stressmeter is then positioned in line with the direction in which the stress is to be measured and is tied off to the rebar cage or a small size supplemental rebar cage, using iron wire, or nylon tie-wraps. A typical installation is shown in Figure 2. Be sure to leave enough slack in the cable so that the stressmeter can be un-tied and positioned vertically for filling.

Figure 2 - Stressmeter ready for concrete pour

As Figure 2 shows, the far end of the stress meter is left open so that when the concrete is poured around the stressmeter the cell can be untied from the rebar and held vertical so that the same concrete can be packed inside the cell, and then the end flange is pushed inside the end of the tube and securely taped in place. **It is of the utmost importance that there be no spaces left inside the cell, so the concrete must be very carefully packed, vibrated and rodded to get rid of all traces of air.** Cables from the stressmeter should be routed carefully so that they are protected from the concrete placement and from traffic.

Additional installation photos are shown in Figure 3 and Figure 4.

Figure 3 - Concrete being poured around the stressmeter

Figure 4 - Another typical stress meter installation

4. LIGHTNING PROTECTION

The Model 4370 Stressmeter, unlike numerous other types of instrumentation available from Geokon, do not have any integral lightning protection components, i.e. transzorbs or plasma surge arrestors. Usually this is not a problem as the stressmeters are installed within concrete or grout and somewhat isolated from potentially damaging electrical transients. However, there may be occasions where some sort of lightning protection is desirable, for example where the stressmeter is in contact with rebar that may be exposed to direct or indirect lightning strikes. Also, if the instrument cable is exposed, it may be appropriate to install lightning protection components, as the transient could travel down the cable to the stressmeter and possibly destroy it.

Note the following suggestions:

- If the stressmeter is connected to a terminal box or multiplexer components such as plasma surge arrestors (spark gaps) may be installed in the terminal box/multiplexer to provide a measure of transient protection. Terminal boxes and multiplexers available from Geokon provide locations for installation of these components.

- Lighting arrestor boards and enclosures are available from Geokon that install at the exit point of the instrument cable from the structure being monitored. The enclosure has a removable top so, in the event the protection board (LAB-3) is damaged, the user may service the components (or replace the board). A connection is made between this enclosure and earth ground to facilitate the passing of transients away from the gauge.

- Plasma surge arrestors can be epoxy potted into the gauge cable close to the sensor. A ground strap would connect the surge arrestor to earth ground, either a grounding stake or the rebar itself.

Consult the factory for additional information on these or alternate lightning protection schemes.

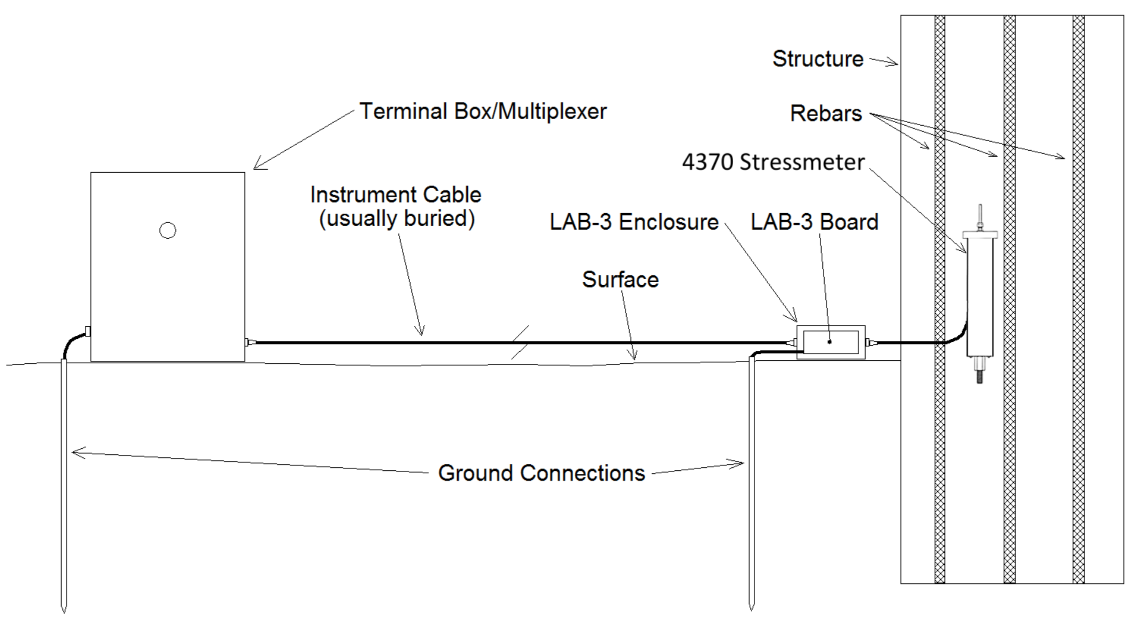

Figure 5 - Lightning Protection Scheme

3. TAKING READINGS

3.1 GK-404 Readout Box

The Model GK-404 Vibrating Wire Readout is a portable, low-power, handheld unit that can run continuously for more than 20 hours on two AA batteries. It is designed for the readout of all Geokon vibrating wire gauges and transducers; and is capable of displaying the reading in either digits, frequency (Hz), period (µs), or microstrain (µε). The GK-404 also displays the temperature of the stressmeter (embedded thermistor) with a resolution of 0.1 °C.

3.1.1 Operating the GK-404

Before use, attach the flying leads to the GK-404 by aligning the red circle on the silver "Lemo" connector of the flying leads with the red line on the top of the GK-404 (Figure 6). Insert the Lemo connector into the GK-404 until it locks into place.

Figure 6 - Lemo Connector to GK-404

Connect each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

To turn the GK-404 on, press the "ON/OFF" button on the front panel of the unit. The initial startup screen will be displayed. After approximately one second, the GK-404 will start taking readings and display them based on the settings of the POS and MODE buttons.

The unit display (from left to right) is as follows:

- The current Position: Set by the **POS** button. Displayed as a letter A through F.
- The current Reading: Set by the **MODE** button. Displayed as a numeric value followed by the unit of measure.
- Temperature reading of the attached gauge in degrees Celsius.

Use the POS button to select position B and the MODE button to select Dg (digits). (Other functions can be selected as described in the GK-404 Manual.)

The GK-404 will continue to take measurements and display readings until the unit is turned off, either manually, or if enabled, by the Auto-Off timer. If the no reading displays or the reading is unstable, see Section 7 for troubleshooting suggestions.

For further information, please refer to the GK-404 manual.

3.2 GK-405 Readout Box

The GK-405 Vibrating Wire Readout is made up of two components: The Readout Unit, consisting of a Windows Mobile handheld PC running the GK-405 Vibrating Wire Readout Application; and the GK-405 Remote Module, which is housed in a weatherproof enclosure and connects to the vibrating wire gauge to be measured. The two components communicate wirelessly. The Readout Unit can operate from the cradle of the Remote Module, or, if more convenient, can be removed and operated up to 20 meters from the Remote Module.

3.2.1 Connecting Sensors

Connecting sensors with 10-pin connectors:
Align the grooves on the sensor connector (male), with the appropriate connector on the readout (female connector labeled senor or load cell). Push the connector into place, and then twist the outer ring of the male connector until it locks into place.

Connecting sensors with bare leads:
Attach the GK-403-2 flying leads to the bare leads of a Geokon vibrating wire sensor by connecting each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

3.2.2 Operating the GK-405

Press the button labeled "POWER ON". A blue light will begin blinking, signifying that the Remote Module is waiting to connect to the handheld unit. Launch the GK-405 VWRA program by tapping on "Start" from the handheld PC's main window, then "Programs" then the GK-405 VWRA icon. After a few seconds, the blue light on the Remote Module should stop flashing and remain lit. The Live Readings Window will be displayed on the handheld PC. Choose display mode "B". Figure 7 shows a typical vibrating wire output in digits and thermistor output in degrees Celsius. If no reading displays or the reading is unstable, see Section 7 for troubleshooting suggestions. For further information, consult the GK-405 Instruction Manual.

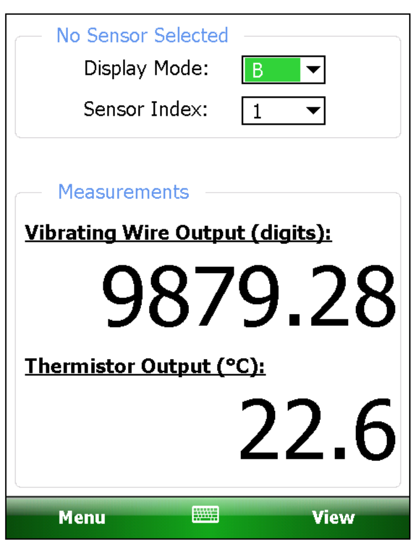

Figure 7 - Live Readings – Raw Readings

3.3 GK-403 Readout Box (Obsolete Model)

The GK-403 can store gauge readings and apply calibration factors to convert readings to engineering units. The following instructions explain taking gauge measurements using Mode "B". Consult the GK-403 Instruction Manual for additional information.

3.3.1 Connecting Sensors

Connecting sensors with 10-pin connectors:
Align the grooves on the sensor connector (male), with the appropriate connector on the readout (female connector labeled senor or load cell). Push the connector into place, and then twist the outer ring of the male connector until it locks into place.

Connecting Sensors with Bare Leads:
Attach the GK-403-2 flying leads to the bare leads of a Geokon vibrating wire sensor by connecting each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

3.3.2 Operating the GK-403

1) Turn the display selector to position "B".

2) Turn the unit on.

3) The readout will display the vibrating wire output in digits. The last digit may change one or two digits while reading.

4) The thermistor reading will be displayed above the gauge reading in degrees centigrade.

5) Press the "Store" button to record the value displayed.

If the no reading displays or the reading is unstable, see Section 7 for troubleshooting suggestions. The unit will turn off automatically after approximately two minutes to conserve power.

3.4 Measuring Temperatures

Each Vibrating Wire Stressmeter is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Geokon readout boxes will read the thermistor and display temperature in °C automatically. To read the thermistor using an ohmmeter, complete the following:

1) Connect the ohmmeter to the two thermistor leads coming from the stressmeter. (Usually white and green.) Since the resistance changes with temperature are large, the effect of cable resistance is usually insignificant.

2) Look up the temperature for the measured resistance in Table 2 in Appendix B.

6. DATA REDUCTION

6.1 Stress Calculation

To convert digits to concrete stress, use the linear or polynomial equation from the calibration report provided with the stressmeter. See Appendix C for a sample calibration report

The **linear** equation is as follows:

$$\text{Concrete Stress } (S) = (R_1 - R_0) \times G$$

Equation 1 - Digits to Concrete Stress (Linear Equation)

Where;
R_1 is the current reading.
R_0 is the initial reading, usually obtained at installation just before the concrete is poured. (NOTE: For greater accuracy use the regression zero found on the calibration report as R_0.)
G is the **linear** gauge factor, in MPa/digit or psi/digit taken from the calibration report.
The cross-sectional area of the Stressmeter is equal to 5.31 sq in.

For example:

If;
Initial field zero reading = 7035 digits
Regression zero = 7071
R_1 = 5219 digits
G = -0.01748 MPa/digit

Then;
The calculated concrete stress using Equation 1 and the **initial field zero =**
S = (5219 – **7035**) x -0.01748 = 31.74 MPa

The calculated concrete stress using Equation 1 and the **regression zero =**
S = (5219 − **7071**) × -0.01748 = 32.37 MPa

The **polynomial** equation is as follows:

$$\text{Concrete Stress (S)} = AR_1^2 + BR_1 + C$$

Equation 2 - Digits to Concrete Stress (Polynomial Equation)

Where;
R_1 is the is the current reading
A and B are the **polynomial gauge factors**, in MPa/digit or psi/digit taken from the calibration report.
C is calculated using the equation:

$$S = AR_1^2 + BR_1$$

Equation 3 - Polynomial gauge Factor C

Where;
S = 0
R_1 is the **initial field zero reading**
A and B are the **polynomial gauge factors**, in MPa/digit or psi/digit taken from the calibration report.

For example:

If;
A = -6.568E-07 MPa/digit
B = -0.009799 MPa/digit
Initial field zero reading = 7035 digits
Current reading = 5219 digits

Then;
C = -6.568E-07*7035^2 - 0.009799*7035 = 101.44

And the calculated concrete stress using **=**
S = 6.658E-07*5219^2 - 0.009799*5219+101.44 = 32.41 MPa

Compare these values to the actual applied stress of 32.47MPa

6.2. Temperature Correction

The Model 4370 Concrete Stressmeter has a coefficient of thermal expansion very similar to the concrete surrounding it so in most cases correction is not necessary.

7. TROUBLESHOOTING

Maintenance and troubleshooting of concrete stressmeters is confined to periodic checks of cable connections and maintenance of terminals. Once installed, the gages are usually inaccessible and remedial action is limited.

Consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: Strain gauge Readings are Unstable

- ✓ Is the readout box position set correctly? If using a datalogger to record readings automatically are the swept frequency excitation settings correct?

- ✓ Is the strain reading outside the specified range (either compressive or tensile) of the instrument?

- ✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators and antennas. Move the equipment away from the installation or install electronic filtering. Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger.

- ✓ Does the readout work with another gauge? If not, the readout may have a low battery or be malfunctioning.

Symptom: Strain gauge Fails to Read

- ✓ Is the cable cut or crushed? This can be checked with an ohmmeter. Nominal resistance between the two gauge leads (usually red and black leads) is 50Ω, ±10Ω. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω /1000' or 48.5Ω/km, multiply by two for both directions). If the resistance reads infinite, or very high (megohms), a cut wire must be suspected. If the resistance reads very low (<10Ω) a short in the cable is likely. Splicing kits and instructions are available from the factory to repair broken or shorted cables. Consult the factory for additional information.

- ✓ Does the readout or datalogger work with another strain gauge? If not, the readout or datalogger may be malfunctioning.

APPENDIX A. SPECIFICATIONS

A.1 4370 Concrete Stressmeter

Standard Range	-3 MPa to +25 Mpa
Resolution	10 kPa
Accuracy[1]	±0.25% F.S.
Temperature Range[2]	-20 to +80 °C
Length × Diameter	600 × 76 mm (I.D. 66 mm)

Table 1 - 4370 Specifications

Notes:
[1] Load cell accuracy
[2] Other ranges available on request

A.2 Thermistor

(See Appendix B also)

Range: -80 to +150° C
Accuracy: ±0.5° C

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3
Resistance to Temperature Equation:

$$T = \frac{1}{A + B(LnR) + C(LnR)^3} - 273.15\ °C$$

Equation 4 - Resistance to Temperature

Where;
T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance.
$A = 1.4051 \times 10^{-3}$ (coefficients calculated over the −50 to +150° C. span)
$B = 2.369 \times 10^{-4}$
$C = 1.019 \times 10^{-7}$

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Table 2 - Thermistor Resistance versus Temperature

APPENDIX C. TYPICAL CALIBRATION REPORT

GEOKON 48 Spencer St. Lebanon, NH 03766 USA

Vibrating Wire Concrete Stressmeter Calibration Report

Model Number: 4370

Calibration Date: February 21, 2013

Serial Number: 1301612

Calibration Instruction: CI-4370-Concrete Stressmeter

Max. Range (lbs): 31000

Technician:

Cable Length: N/A

Initial Cycling Data

Load (lbs):	0	0	35000	0
Reading:	7045	7038	4441	7035

Applied Load in lbs.	Applied Stress in psi	Applied Stress in MPa	Cycle 1 Gage Readings	Cycle 2 Gage Readings	Average (2 cycles)	Change	Linear Error (% FS)	Polynomial Error (% FS)
0	0	0.00	7035	7037	7036		1.52	0.30
5000	942	6.49	6704	6706	6705	331	-0.24	-0.35
10000	1883	12.99	6345	6349	6347	358	-0.83	-0.14
15000	2825	19.48	5982	5982	5982	365	-1.11	-0.05
20000	3766	25.98	5603	5603	5603	379	-0.78	0.21
25000	4708	32.47	5219	5218	5219	385	-0.22	0.22
30000	5650	38.96	4829	4825	4827	392	0.65	0.04
31000	5838	40.26	4752	4754	4753	74	0.63	-0.23
0	0	0.00	7036	7034	7035			

Linear Gage Factor (G): -2.535 **psi/digit** -0.01748 **MPa/digit** **Regression Zero (R_0):*** 7071

Polynomial Gage Factors psi: **A:** -9.524E-05 **B:** -1.421 **C:** ______

MPa: **A:** -6.568E-07 **B:** -0.009799 **C:** ______

Calculate C by setting S=0 and R_1 = initial field zero reading in the polynomial equation

Calculated Stress, S_1: **Linear, $S = G(R_1 - R_0)$**

Polynomial, $S = AR_1^2 + BR_1 + C$

Linearity = ((Calculated Stress - Applied Stress) / Max. Applied Stress) x 100%

* Note: The above calibration uses a linear regression method. The Zero Reading shown is for the best straight line computation and does not usually agree with the actual no-load reading.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Figure 8 - Typical Calibration Report