CGEO INSTRUMENTS

CGEO INTERNATIONAL LIMITED

Model CGEO-SG5

Rebar Vibrating Wire Strain Gauge

Installation Manual

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1. INTRODUCTION

CGEO-SG5 Vibrating Wire Rebar Strain Gauges are designed primarily for monitoring the stresses in reinforcing steel in concrete structures, such as bridges, concrete piles and diaphragm walls. The Strain Gauge is comprised of a length of high strength steel, bored along its central axis to accommodate a miniature vibrating wire strain gage. Readout of load or stress is achieved remotely using a portable readout or datalogging system available from Beijing Soil Instruments Ltd.

The Model CGEO-SG5 Vibrating Wire Rebar Strain Gauge consists of a short length of high strength steel welded between two long sections of reinforcing bar. It is designed to be welded between sections of structural concrete reinforcing bar. The cable exits from the Strain Gauge via a compression fitting. See Figure 1.

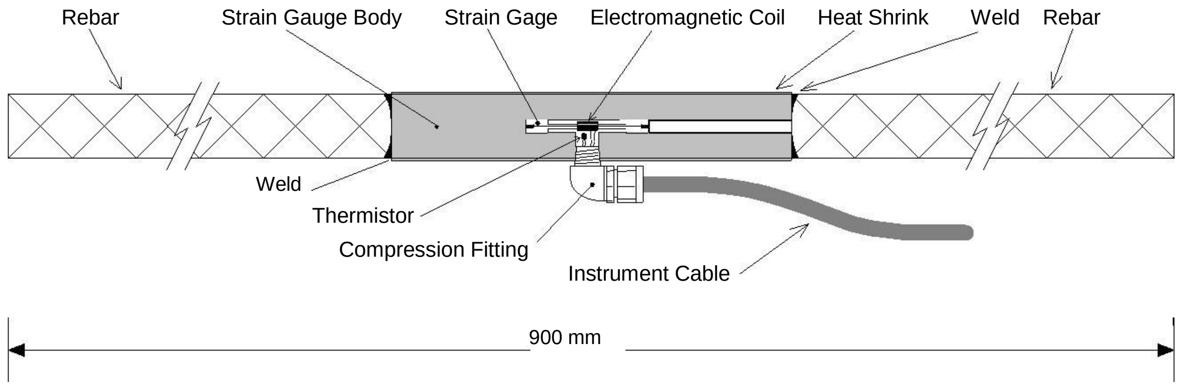

Figure 1 - Model CGEO-SG5 Rebar Strain Gauge

The Model CGEO-SG5-12 (diameter 12) Vibrating Wire Rebar Strain Gauge or "Sister Bar" consists of a short length of high strength steel welded between two long sections of reinforcing bar. It is designed to be wire tied in parallel with the structural rebar. The small diameter of the bar minimizes its affect on the sectional modulus of the concrete. The cable exits from the Strain Gauge through a small block of protective epoxy. See Figure 2.

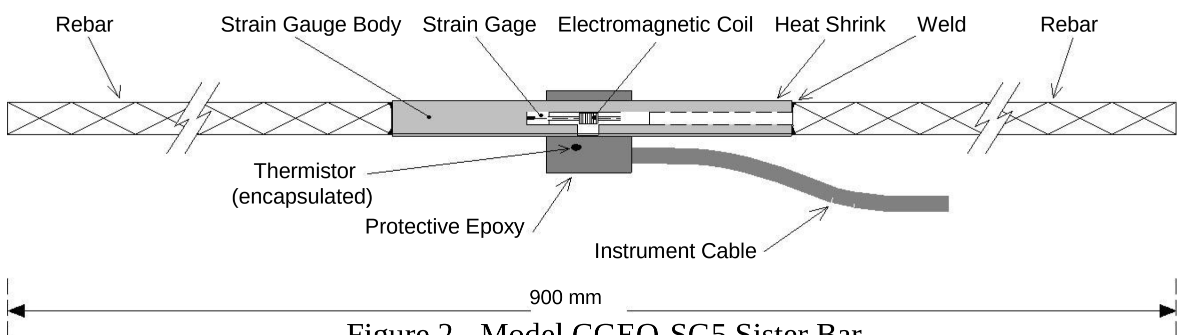

Figure 2 - Model CGEO-SG5 Sister Bar

Both models of Strain Gauges are robust, reliable and easy to install and read, and are unaffected by moisture, cable length or contact resistance. The long term stability of these instruments has proven to be excellent.

2. INSTALLATION

2.1. Preliminary Tests

It is always wise, before installation commences, to check the Strain Gauges for proper function. Each Strain Gauge is supplied with a calibration sheet that shows the relationship between readout digits and microstrain and also shows the initial no load zero reading. The Strain Gauge electrical leads (usually the red and black leads) are connected to a readout box (see section 3) and the zero reading given on the sheet is now compared to a current zero reading. Under normal circumstances the two readings should not differ by more than about 25 digits (10 microstrain). Shipping shocks may, however, cause larger shifts. If the reading is within 100 digits (40 microstrain) of the factory zero, and is stable, it is safe to proceed with the installation.

By pulling on the Strain Gauge it should be possible to change the readout digits, causing them to rise as tension increases.

Checks of electrical continuity can also be made using an ohmmeter. For the CGEO-SG5, resistance between the gage leads should be approximately 180 ±10 ohm. Remember to add cable resistance when checking (stranded copper leads are approximately 50ohm /km, multiply by 2 for both directions). Between the green and white should be approximately 3000 ohms at 25 °(see Table B-1), and between any conductor and the shield should exceed 50 megohm.

Note: Do not lift the Strain Gauge by the cable.

2.2. Rebar Strain Gauge Installation

2.2.1. Model CGEO-SG5

The normal procedure is to weld the Strain Gauge in series with the reinforcing steel that is to be instrumented on the site. For a typical installation see Figure 3. The Strain Gauge is long enough so that it may be welded in place without damaging the internal strain gage element (Figure 1).

However, care should still be taken to ensure that the central portion of the Strain Gauge does not become too hot as the plucking coil and protective epoxy could melt. In order to prevent this it may be necessary to place wet rags between the weld area and the coil housing. Also, take care not to damage or burn the instrument cable when welding. After welding, route the instrument cable along the rebar system and tie it off every 3-4 feet (1 meter) using nylon cable ties. Avoid using iron tie wire to secure the cable as the cable could be cut.

Be sure when installing the Strain Gauges to note the location and serial numbers of all instruments. This is necessary for applying the proper calibration factors and determining strain characteristics when reducing data.

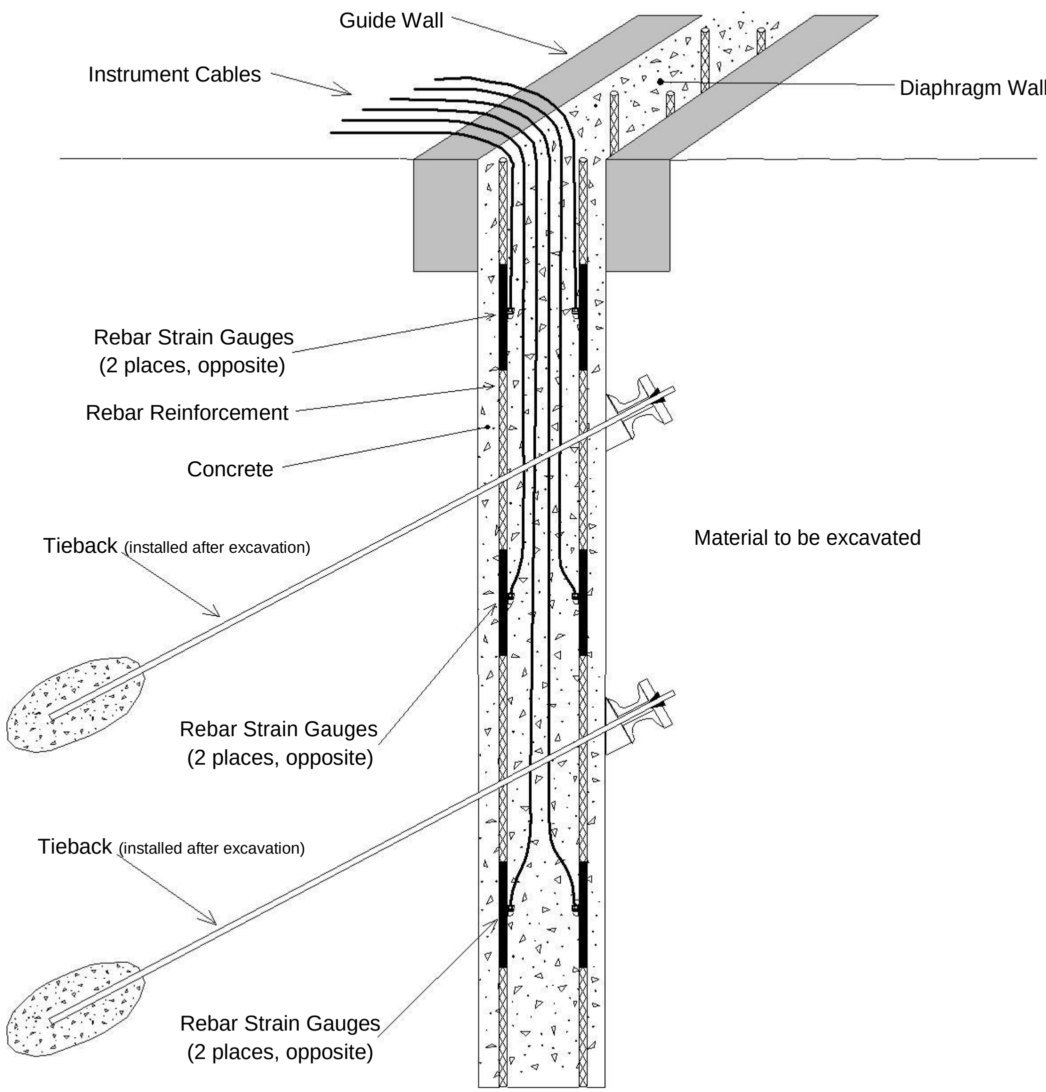

Figure 3 - Model CGEO-SG5 Installation

2.2.2. Model CGEO-SG5-12 "Sister Bar"

The "Sister Bar" is usually installed using standard iron tie wire. Normally ties near the ends and at the one third points are sufficient if the gage is being wired to a larger section of rebar or to horizontal bars. Wiring at the one third points alone is sufficient if the gage is being wired in parallel to the structural rebar. See Figures 4 and 5. Route the instrument cable along the rebar system and tie it off every 3-4 feet (1 meter) using nylon cable ties. Avoid using the tie wire on the instrument cable as it could cut the cable.

Be sure when installing the Strain Gauges to note the location and serial numbers of all instruments. This is necessary for applying the proper calibration factors and determining load characteristics when reducing data.

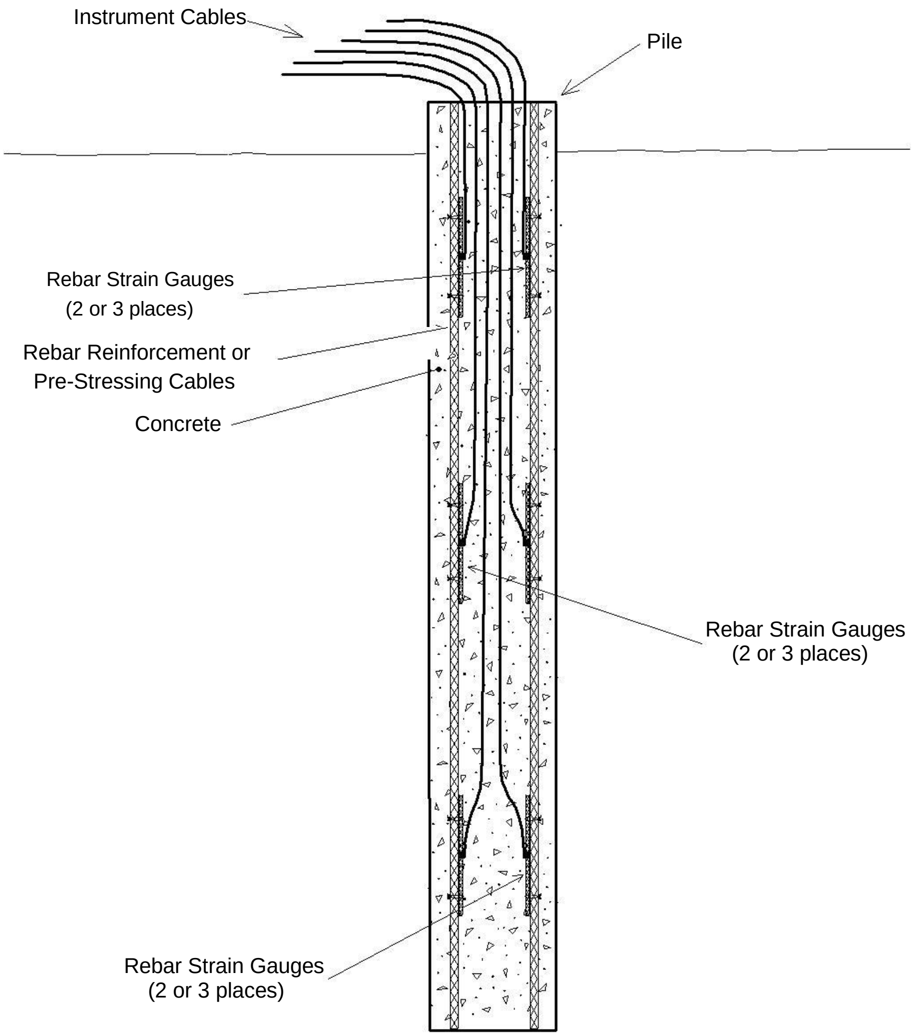

Figure 4 - Model CGEO-SG5 "Sister Bar" Installation

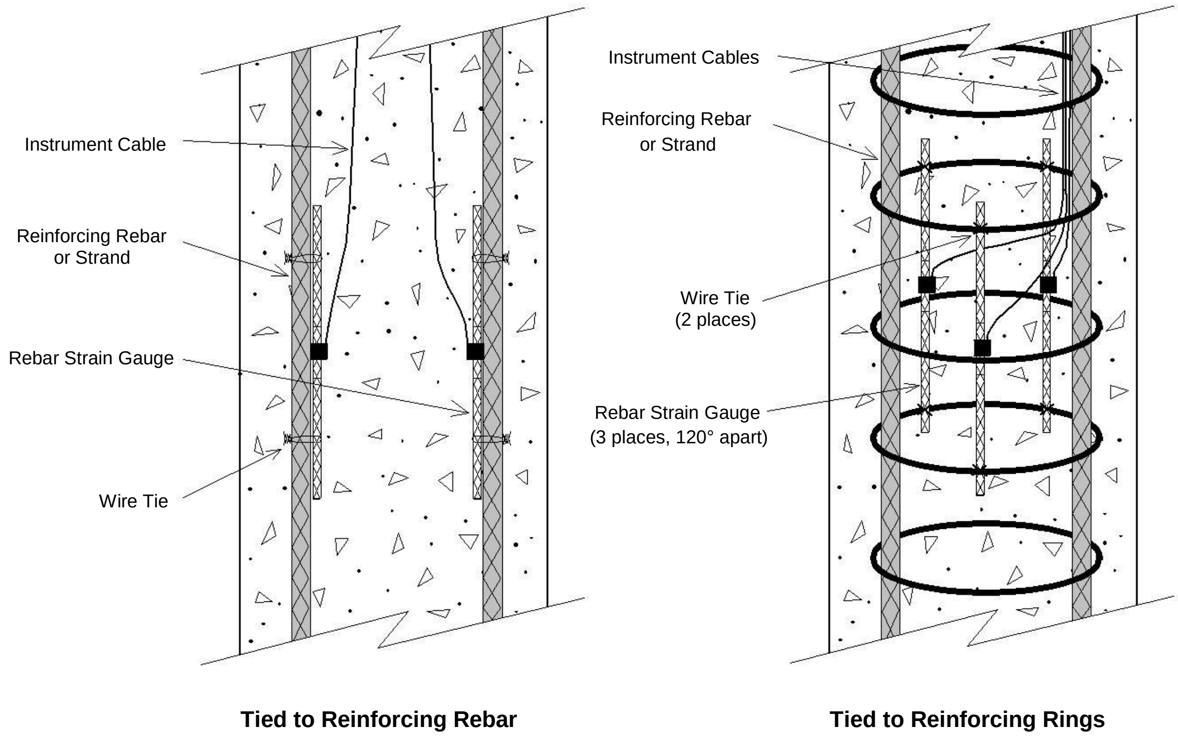

Figure 5 - Model CGEO-SG5 "Sister Bar" Installation Detail

2.3. Cable Installation

As noted in the installation sections, route the instrument cables along the structural rebar and tie off using nylon cable ties every 2-3 feet (1 meter) to secure. Outside of the instrumented structure, the cable should be protected from accidental damage caused by moving equipment or other construction activity.

Cables may be spliced to lengthen them, without affecting gage readings. Always waterproof the splice completely, especially when embedding within the concrete, preferably using an epoxy based splice kit such the 3M Scotchcast , model 82-A1. These kits are available from the factory.

3. TAKING READINGS

3.1. Operation of the BSIL-RO-VW Readout Box

BSIL-RO-VW readout is suitable for all BSIL vibrating wire sensors.

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the white and green clips are for the thermistor and the blue for the shield drain wire.

1. Turn the display selector to position "B". Readout is frequency module and temperature in ℃.
2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Press the "Store" button to record the value displayed. If the no reading displays or the reading is unstable see section 5 for troubleshooting suggestions. The thermistor will be read and output directly in degrees centigrade.
3. Turn off the readout. Or the unit will automatically turn itself off after approximately 15 minutes to conserve power.

3.2. Measuring Temperatures

Each Vibrating Wire Rebar Strain Gauge is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Usually the white and green leads are connected to the internal thermistor. BSIL-RO-VW readout will read the thermistor and display temperature by connecting its white and green leads to white and green leads of rebar strain gauge.

Following is instruction of using ohmmeter to read temperature:

1. Connect the ohmmeter to the two thermistor leads coming from the Strain Gauge. (Since the resistance changes with temperature are so large, the effect of cable resistance is usually insignificant.)
2. Look up the temperature for the measured resistance in Table B-1. Alternately the temperature could be calculated using Equation B-1.

4. DATA REDUCTION

4.1. Strain Calculation

The basic units utilized by Soil for measurement and reduction of data from Vibrating Wire Rebar Strain Gauges are "digits". Calculation of digits is based on the following equation;

$$\textbf{Digits} = \textbf{Hz}^2/1000$$

Equation 1 - Digits Calculation

To convert digits to strain the following equation applies;

$$F = (R_1 - R_0)\,G$$

Equation 2 – Strain Caculation

Where: R_0 is the initial reading in digits, usually obtained at installation or at the commencement of a test.

R_1 is the current reading in digits.

G is the calibration factor from the supplied calibration sheet (see Figure 6).

For example, assume an initial reading, R_0, of 8000 digits, a current reading, R_1, of 7700, and a calibration factor, G, of 0.718439 microstrain per digit.

F= (7700 - 8000)* 0.718439 = - 215.5217 (compression)

Symbol rule: “-”： compression, “+”: tension

4.2. Temperature Correction

Rebar Strain Gauges are usually embedded in concrete and strained by the concrete, the assumption being that ***the strain in the meter is equal to the strain in the concrete***. When the temperature changes, the concrete expands and contracts at a rate slightly less than the rate of the steel of the vibrating wire. The coefficients of expansion are:

Steel (K_{steel}):	12.2 ppm/ ℃	6.7 ppm/ ℉
Concrete ($K_{concrete}$):	10 ppm/ ℃	5.5 ppm/ ℉
Difference (K):	2.2 ppm/ ℃	1.2 ppm/ ℉

Table 1 - Thermal Coefficients

Hence a correction is required to the apparent strains equal to the difference of these two coefficients. See Equation 3.

$$F = G\,(R_1 - R_0) + K\,(T_1 - T_0)$$

Equation 3 – Load Related Strain

Where: T_0 is the initial temperature recorded at the time of installation.

T_1 is the current temperature.

K is the thermal coefficient.

Normally the effect of temperature to VW strain gauge is little, it needn't to be corrected. Detail calculation method see calculation equation and related factor in calibration certificate.

4.3. Environmental Factors

Since the purpose of the Strain Gauge installation is to monitor site conditions, factors which may affect these conditions should be observed and recorded. Seemingly minor effects may have a real influence on the behavior of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to: blasting, rainfall, tidal or reservoir levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

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REBAR VW SISTER BARS CALIBRATION CERTIFICATE

Model: BSIL-ST5-16 — **Readout: BSIL-RO-VW**
Temperature：20 ℃ — **Humidity：46%RH**

Testing Result

Series Number：1334216 — **Range：1000μ**

Applied Pressure (KN)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Gage Reading 3rd Cycle	Average Gage	Calculated Pressure Linear	Error Linear (%FS)	Calculated Pressure Polynomial	Error Polynomial (%FS)
0.0	3286.6	3286.5	3286.3	3286.5	0.1149	0.29	0.0312	0.08
8.0	3575.8	3576.1	3575.8	3575.9	7.930	-0.17	7.945	-0.14
16.0	3871.2	3872.9	3872.2	3872.1	15.928	-0.18	15.995	-0.01
24.0	4169.3	4170.3	4169.6	4169.7	23.97	-0.09	24.03	0.08
32.0	4466.8	4467.6	4466.5	4467.0	31.99	-0.02	32.01	0.03
40.0	4765.4	4766.7	4765.9	4766.0	40.07	0.17	39.98	-0.04

Calculated:
Linear F= $G(R_1-R_0) + K(T_1-T_0)$
Polynomial F= $AR_1^2 + BR_1 + C + K(T_1-T_0)$

(με)Linear Gage Factor： G = 0.671544με/Digit
(με) Polynomial Gage Factors: A = -0.0000071578066141
B = 0.7291766179015680
C = -2318.34416931388000
Thermal Factor: K = -0.52017με/℃
R_0....Original Reading
T_0....Original Temperature

Checked by : Gaosong Collator: Zhaocui Certified by: Wuqijun
Calibration Date: 27/Mar/13

Kong.

E

N

ccuracy

(%FS)

-0.08
0.18
-0.07
-0.08
0.03
0.01

Figure 6 - Sample Model CGEO-SG5 Calibration Sheet

5. TROUBLESHOOTING

Maintenance and trouble shooting of Vibrating Wire Rebar Strain Gauges are confined to periodic checks of cable connections. Once installed, the meters 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? Channel B of the BSIL-RO-VW readout can be used to read the Strain Gauge.
- ✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators and antennas. Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger.
- ✓ Check whether the connection of readout and strain gauge's leads is well. Does the readout work with another Strain 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. For the CGEO-SG5, nominal resistance between the two gage leads (usually red and black leads) is 180ohm+/-10, Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 50ohm /km, multiply by 2 for both directions). If the resistance reads infinite, or very high (megohms), a cut wire must be suspected. If the resistance reads very low (＜20 ohm) a short in the cable is likely.
- ✓ Does the readout or datalogger work with another Strain Gauge? If not, the readout or datalogger may be malfunctioning.

APPENDIX A - SPECIFICATIONS

A.1. Rebar Strain Gauges

Model	CGEO-SG5 “sister bar”	CGEO-SG5	
Standard Ranges	210MPa(1000με)	300MPa(1500με)	400MPa(2000με)
Diameter	12mm	14, 16, 18, 20, 22, 25, 28, 32, 36, 40mm	25, 28, 32, 36, 40mm
Accuracy	0.25％F.S.		
Resolution	0.016％F.S.		
Temperature Range	-20 ~ +80℃		
Water Proof	customized 0.5, 2MPa available or others		
Connecting Bar	high strength whorl steel or steel		

Table A-1 Model CGEO-SG5 Rebar Strain Gauge Specifications

Notes:
[1]Consult the factory for other sizes available.

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:

$$T \quad \frac{1}{A \quad B(LnR) \quad C(LnR)^{3}} \quad 2732.$$

Equation B-1 Convert Thermistor Resistance to Temperature

Where; T： Temperature in C.

LnR：Natural Log of Thermistor Resistance

A： 1.4051 10^{-3} (coefficients calculated over the 50 to +150 C. span)

B：2.369 10^{-4}

C：1.019 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 B-1 Thermistor Resistance versus Temperature