A Benchmark Problem on Structural Health Monitoring of High-Rise Slender Structures

Phase I: Field vibration measurement and model updating

Description of the measurement

General

This set of ambient vibration measurement data is extracted from the in-construction health monitoring system installed on the Guangzhou New TV Tower. The data were recorded from 18:00 pm on 19 January 2010 to 18:00 pm on 20 January 2010, lasting 24 hours. The acceleration, wind direction, wind speed and ambient temperature were measured during the period. Format of the data will be described later.

Sensors

20 uni-axial accelerometers (Tokyo Sokushin AS-2000C) were employed for vibration measurement in this study. The frequency range is DC-50 Hz (3dB), amplitude range ±2 g, and the sensitivity 1.25 V/g.

During the construction stage, one anemometer (RM Young, 05103L) was used to measure the wind direction and wind speed. The measurement range is 0 ~ 100 m/s and output signal is electric current type so that the signal can be transmitted to the acquisition unit about 100 m away. One thermocouple (PT100) was installed besides the anemometer to measure the air temperature.

Datasheets of the accelerometer and anemometer are attached in the end of this file.

Sensor Placement

20 uni-axial accelerometers were installed at eight levels as shown in Fig. 1, considering the availability of space and accessibility to the data acquisition units. The 4th level and the 8th level were equipped with four uni-axial accelerometers, two for measurement of the horizontal acceleration along the long-axis of the inner structure and the other two for the short-axis. At the other six levels, each section was equipped with two uni-axial accelerometers, one along the long-axis of the inner structure and the other along the short-axis of the inner structure. Fig. 2 shows a plan of the section and the measurement directions of acceleration. The sensors were mounted firmly to the shear wall of the inner structure via a steel angle. Orientation of each accelerometer was determined by the positioned bolts that have been located accurately before installation. After calibrating the orientation, the sensors were locked in a steel box for protection.

The anemometer was installed at the top of the main tower where the altitude is 461.1 m. The position of the installed anemometer is shown in Fig. 3.

Data Acquisition System

To reduce the noise due to long cables in the conventional centralized data acquisition system, a de-centralized system was specially designed in the project and, at the same time to account for data synchronization. At each level, an acquisition unit was employed to collect the acceleration data from the two (or four) sensors at this level. The total eight acquisition units were connected in series via two cables, one for synchronization and the other for acceleration data transmission. One PC placed in the Tower was responsible for sending synchronization signal and collecting acceleration data. The configuration of the system is illustrated in Fig. 1. A bandwidth filter of 0.05 Hz to 40 Hz was designed for each acquisition unit. The system has 24 bit A/D converters. An amplifier was used in each unit to amplify the acceleration signal by 1000 times.

The acquisition unit at the top level is also responsible to record the data from the anemometer. The temperature data were recorded by another static data logger.

The sampling frequency of the acceleration and wind data was set to 50 Hz. The temperature data were measured every minute (1/60 Hz).

Data Description

The acceleration, wind direction, and wind speed data during one hour period were stored as one text file with a sampling frequency of 50 Hz. The ambient temperature was measured per minute. Consequently there are totally 73 text files (24 for acceleration, 24 for wind direction, 24 for wind speed, and one for temperature) totally with an uncompressed storage size of 1.42 GB or a compressed size of 420 MB in format of ZIP.

The users can download the measurement data in two manners. The first way is to download all the 73 files in one ZIP file at http://www.cse.polyu.edu.hk/benchmark/Phase I data/Phase I data_all.zip. As the internet connection may be not smooth sometimes, one can download 27 files individually: the compressed acceleration at each hour can be downloaded individually at http://www.cse.polyu.edu.hk/benchmark/Phase_I_data/accdata_2010-01-??-**.zip where ?? is 19 or 20 (denoting date) and ** is 00 to 23 (denoting hour); the wind direction during the 24 hours can be downloaded at http://www.cse.polyu.edu.hk/benchmark/Phase_I_data/Wind direction_24_hours.zip; the wind speed during the 24 hours can be downloaded at http://www.cse.polyu.edu.hk/benchmark/Phase_I_data/Wind_speed_24_hours.zip; and the temperature data is http://www.cse.polyu.edu.hk/benchmark/Phase_I_data/Temperature_24 hours.txt.

The unzipped files are text type on format of ASCII. For example, the file *accdata_2010-01-19-18.txt* comprises the acceleration recorded from 18:00 pm to 19:00 pm on 19 January 2010. It has 20 columns and 180,000 rows. Each column represents the acceleration data (unit: m/s^2) of one channel during the hour ($3,600 \times 50 = 180,000$). The channel labels are also shown in Fig. 1 and Fig. 2. For example, the first column of the file is the acceleration data corresponding to channel #01 in the figures, i.e., the strong-axis direction on the 1st section. The size of the file is 56,602 KB.

The unzipped wind speed data file contains one column only and 180,000 rows (unit: m/s). The wind direction data file has the same size (unit: degree to due north). It is noted that all acceleration data and wind data are synchronized.

The temperature data file contains 24 hours' temperature with a size of 1440 data points (24 ×60 = 1440).

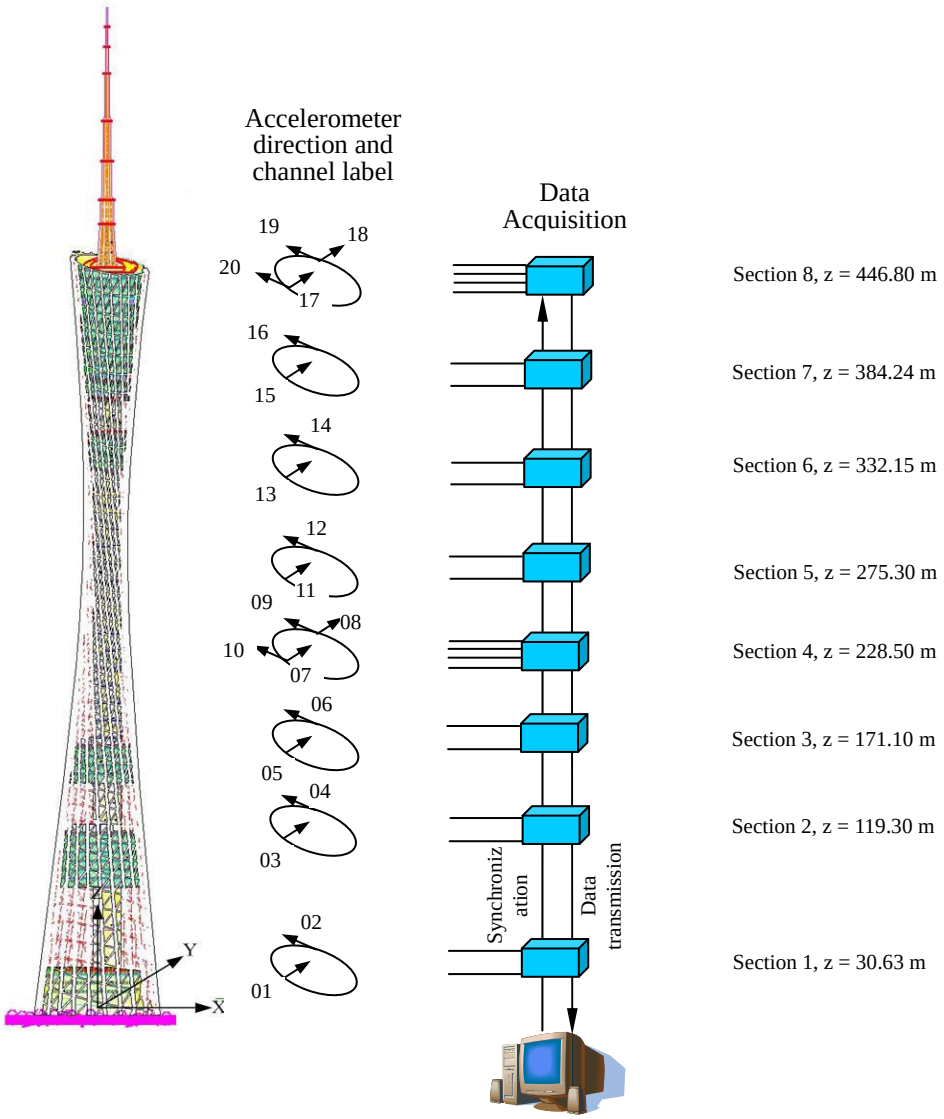


Fig. 1 Position of the accelerometers and data acquisition system

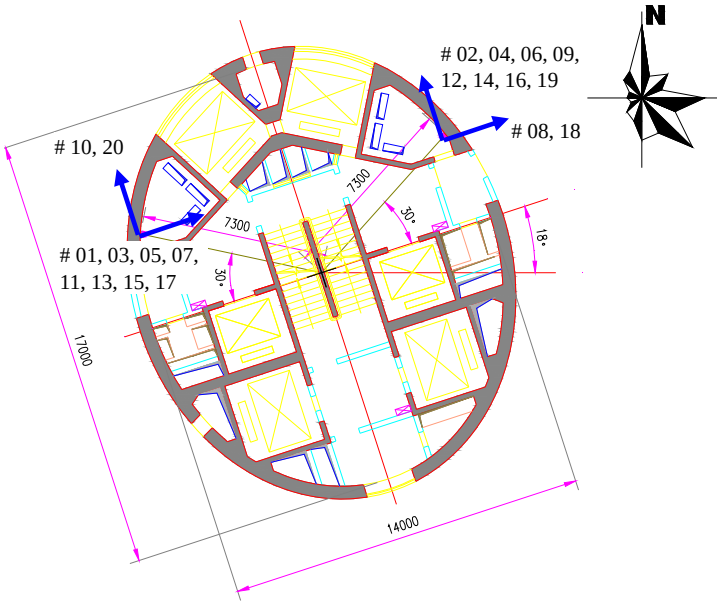


Fig. 2 Measurement directions of acceleration and channel labels

Fig. 3 Anemometer at top of the main tower (z = 461.1 m)

Appendices – Sensor Datasheet

High Resolution SERVO ACCELERMETER AS-2000 (C)

Tokyo Sokushin
13-14-34, Ougi, Adachi-Ku, Tokyo, Japan
TEL:81-3-3855-5911 AX:81-3-3855-5921
http://www.to-soku.co.jp

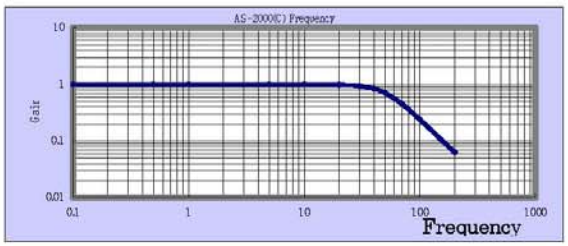
Low Power、Waterproof Accelerometer for Seismic Measurement

±2000gal Full range
DC～50Hz, Bandwidth
0.001gal Resolution

Uni-axial Model
AS-2000 (C) (40×40×70)

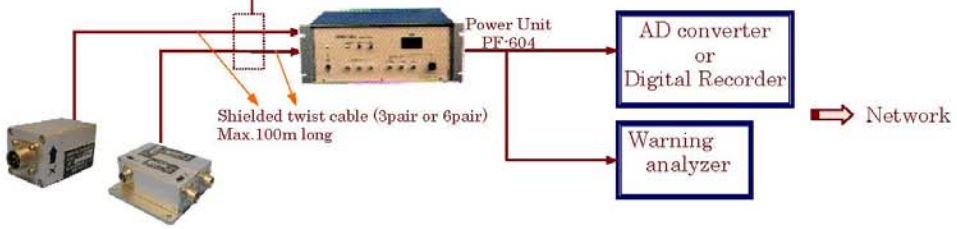
Tri-Axis mount
AS-2000 (C) ×3

Frequency Response



SEISMOCORDER
CV-574C
CV-575C

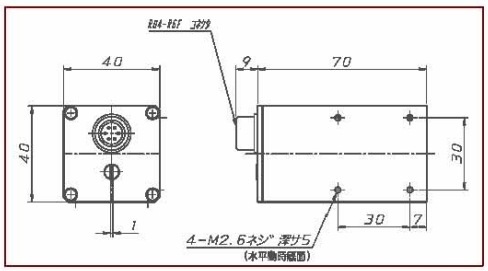
Practical Use



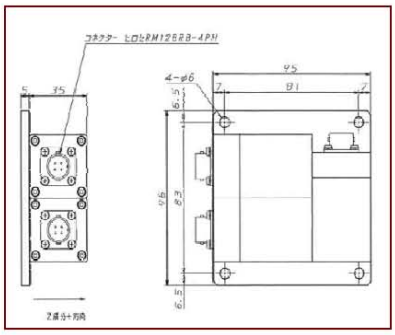
◆Specifications

Sensor	
Model	ＡＳ－２０００(C)
Mode of operation	Uni-axial
Bandwidth	DC～50Ｈｚ （±3dB）
Full Scale Range	±2000 gal
Scale Factor	1.25 mV/gal
Output Resistance	100Ω
Dynamic Range	126dB
Linearity	0.03% of full scale
Damping Ratio	h＝0.6～0.7
Sensitivity Axis to case Alignment	±1 degree max.
Output noise	1μVrms (0.1～10Hz)
Cross Axis Sensitivity	0.003 G/G
Offset Adjust	Possible by a trim-screw
Calibration Coil (Self Cal.)	10μA/Gal
Power Requirement	±5VDC
Current Consumption	5mA
Operating Temperature	－20℃～＋70℃
Thermal Coefficient of Sensitivity	0.02%/℃
Thermal Coefficient of drift	0.02%/℃
Shock Survival	30G (less than 0.1)
Waterproof	30kpa
External Dimensions	40×40×70mm
Weight	250gr

Dimension



AS-2000 (C)



AS-2000 (C)x3

Tokyo Sokushin Co.,Ltd

Office: 3-14-34, Ougi, Adachi-Ku. Tokyo. Japan
TEL:81-3-3855-5911 AX:81-3-3855-5921
http://www.to-soku.co.jp

YOUNG

Model 05103 **Wind Monitor**

The Wind Monitor is a high performance, rugged wind sensor. Its simplicity and corrosion-resistant construction make it ideal for a wide range of wind measuring applications.

The wind speed sensor is a four blade helicoid propeller. Propeller rotation produces an AC sine wave voltage signal with frequency directly proportional to wind speed. Slip rings and brushes are eliminated for increased reliability.

The wind direction sensor is a rugged yet lightweight vane with a sufficiently low aspect ratio to assure good fidelity in fluctuating wind conditions. Vane angle is sensed by a precision potentiometer housed in a sealed chamber. With a known excitation voltage applied to the potentiometer, the output voltage is directly proportional to vane angle. A mounting orientation ring assures correct realignment of the wind direction reference when the instrument is removed for maintenance.

The instrument is made of UV stabilized plastic with stainless steel and anodized aluminum fittings. Precision grade, stainless steel ball bearings are used. Transient protection and cable terminations are in a convenient junction box. The instrument mounts on standard 1 inch pipe.

For offshore and marine use, **Model 05106, Wind Monitor-MA** features special waterproof bearing lubricant and a sealed, heavy duty cable pigtail in place of the standard junction box. Separate signal conditioning for voltage or current outputs is available.

The Wind Monitor is available with two additional output signal options. **Model 05103V** offers calibrated 0-5 VDC outputs, convenient for use with many dataloggers. **Model 05103L** provides a calibrated 4-20 mA current signal for each channel, useful in high noise areas or for long cables (up to several kilometers). Signal conditioning electronics are integrated into the sensor junction box.

Specifications

Range:
Wind speed: 0-100 m/s (224 mph)
Azimuth: 360° mechanical, 355° electrical (5° open)

Accuracy:
Wind speed: ±0.3 m/s (0.6 mph) or 1% of reading
Wind direction: ±3 degrees

Threshold:*
Propeller: 1.0 m/s (2.2 mph)
1.1 m/s (2.4 mph) 05106
Vane: 1.1 m/s (2.4 mph) 05103

Dynamic Response:*
Propeller distance constant (63% recovery) 2.7 m (8.9 ft)
Vane delay distance (50% recovery) 1.3 m (4.3 ft)
Damping ratio: 0.3
Damped natural wavelength: 7.4 m (24.3 ft)
Undamped natural wavelength: 7.2 m (23.6 ft)

Signal Output:
Wind speed: magnetically induced AC voltage, 3 pulses per revolution. 1800 rpm (90 Hz) = 8.8 m/s (19.7 mph)
Azimuth: analog DC voltage from conductive plastic potentiometer – resistance 10K Ω, linearity 0.25%, life expectancy – 50 million revolutions

Power Requirement:
Potentiometer excitation: 15 VDC maximum

Dimensions:
Overall height: 37 cm (14.6 in)
Overall length: 55 cm (21.7 in)
Propeller: 18 cm (7 in) diameter
Mounting: 34 mm (1.34 in) diameter (standard 1 inch pipe)

Weight:
Sensor weight: 1.0 kg (2.2 lbs)
Shipping weight: 2.3 kg (5 lbs)

**Nominal values, determined in accordance with ASTM standard procedures.*

MODEL 05103V **0-5 VDC outputs**

Power Requirement:
8-24 VDC (5 mA @ 12 VDC)

Operating Temperature:
-50 to 50°C

Output Signals:
0-5.00 VDC full scale

MODEL 05103L **4-20 mA outputs**

Power Requirement:
8-30 VDC (40 mA max.)

Operating Temperature:
-50 to 50°C

Output Signals:
4-20 mA full scale

CE *Complies with applicable CE directives.*
Specifications subject to change without notice.

Ordering Information — MODEL

WIND MONITOR	**05103**
WIND MONITOR 0-5 VDC OUTPUTS	**05103V**
WIND MONITOR 4-20 mA OUTPUTS	**05103L**
WIND MONITOR-MA (MARINE MODEL)	**05106**
WIND SENSOR INTERFACE (FOR USE WITH 05106) 0-5 VDC	**05603C**
WIND LINE DRIVER (FOR USE WITH 05106) 4-20 mA	**05631C**

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