

Measuring Consultants Guide



MEASURING CONSULTANTS



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● Construction Management and Dynamic Behavior Monitoring System

● Guide to Various Measuring Consultants

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- ② Caisson measurement
- ③ Retaining wall measurement
- ④ Test pavement measurement
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- ⑥ Fill measurement
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Tokyo Sokki Kenkyujo Co., Ltd.

TML Measurement consulting service offers a secure delivery of satisfactory information and results with the optimum technology according to the customer's project.

There are a great variety of structures constructed using many different techniques. Information needed to prepare optimum designs for them and to construct and maintain them safely and efficiently can only be acquired by conducting appropriate measurement activities. TML has experience and expertise accumulated over many years of design, production and application operations. As an expert in measurement, TML knows sites and site work thoroughly and makes the most of its know-how to provide customers with measurement consulting services.

When TML is asked for measurement consultants

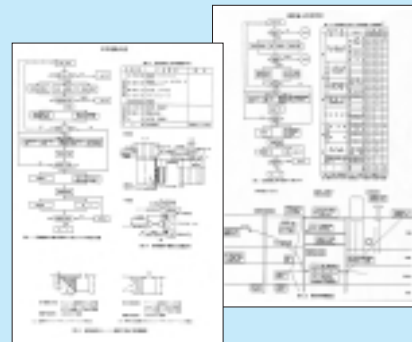
TML's Measuring Consultants enable a customer to acquire precise, reliable measurement and analysis data.

It is not always easy to acquire reliable measurement data. Reliable data can only be acquired by the following appropriate steps most suitable for a purpose of measurement or a type of structure. Based on characteristics of an object of measurement and site conditions, TML determines what type of information is needed and how that information can be acquired by measurement. TML performs all measurement activities for a customer from selection and installation of measuring instruments to analysis of collected data. TML provides a customer with precise, reliable measurement and analysis data.

Compliance with the proximity evaluation criteria and measurement items established by Japan's major construction work operators

In executing construction work, it is important to ensure work safety and to estimate the effects of construction work on adjacent structures. The proximity evaluation criteria are established by such construction work entities as the Ministry of Construction and local governments. TML's measuring instruments and measurement activities comply with the measurement items specified in the proximity evaluation criteria.

■ Registered construction consultant number: Construction 19, 6021 for soil and foundation categories



Required data can be obtained with minimum time and cost.

A measurement process consists of a number of steps, from planning to selection and installation of measuring instruments to calibration and adjustment. Considerable time and cost are involved in this process. TML provides consulting services by using its expertise, experience, a full line of jigs, tools and measuring instruments, and a professional staff. A customer can get required measurement data with minimum necessary time and cost.

TML knows all about diverse objects of measurement

TML knows all about sites where measurement is made. Objects of measurement range from retaining walls and embankments to bridges, tunnels, dams, and other structures. Required measurement techniques and measuring instruments vary, depending on site conditions. TML has developed a wide variety of measuring instruments based on customer needs and has cultivated deep understanding and know-how on diverse objects of measurement, their characteristics, and operating conditions for measuring instruments. Experience and expertise accumulated over years enable TML to propose the most appropriate measurement solution for each individual measurement project and to carry out measurement with a high level of accuracy and efficiency.

■ Objects of measurement

Construction management	Bridge	Retaining Wall	Landslide	Marine structure
Road Airport	Fill	Railway	Tunnel	Underground opening
Dam	Caisson	Energy plant	Dome	Various machines
Automobile	Aircraft	Shipbuilding	etc.	

■ Special measurement management

Small FWD (FWD-Light)	Test pavement	Histogram analysis
SIT - Nuclear power plant	Vibration measurement	

■ Measurement items

Strain	Displacement	Deformation	Axial force	Tensile force
Bending	Shearing	Torque	Frictional force	Residual stress
Pressure	Wind pressure	Soil pressure	Water pressure	Wave pressure
Acceleration	Velocity	Vibration	Stress frequency	Temperature
Settlement	Inclination	Expansion	Landslide	Convergence
Crack displacement	Pore water pressure	Underground water level	etc.	

TML knows the entire measurement process

A measurement process starts with planning and ends with data analysis. The accuracy of measurement suffers if any one task to be performed in steps from planning to data analysis is accomplished incompletely. To bring maximum results from minimum costs, it is necessary to prepare a detailed plan with consideration of measurement conditions and to execute each specific measurement task completely in all steps of a measurement process. By taking advantage of its experience and expertise, TML is able to control the entire measurement process and to achieve the best measurement results through the coordination of a professional staff.

TML makes the most of its lineup of products to provide the best measurement consulting services

TML, an all-around manufacturer of strain measuring instruments, is known for its diverse products designed to deliver the best measurement performance under any site conditions. There is no company that parallels TML in terms of a lineup of versatile measuring instruments that can be used for all measurement tasks from planning to data processing. To provide customers with efficient consulting services and accurate data, TML chooses measuring instruments most suitable for each purpose and uses them in such ways that they can give the most reliable measurements.

Strain gauges

These measure strain or stress on metals, concrete, and other materials. They are also used as sensing devices for transducers. They are high-reliability products, though small in size and simple in structure. TML provides about 8,000 types of strain gauges designed for specific applications and objects of measurement.

General use transducers

These are sensors and used to measure load, pressure, displacement, acceleration, and other various physical quantities. When strain occurs on an object of measurement, strain equal to the physical quantity of that actual strain occurs in the transducer and it is detected using a built-in strain gauge. These are small in size and lightweight and have superior linearity and stability characteristics. Many different types of general-use transducers are available so that a customer can choose one suitable for an object of measurement or its capacity. TML continues to improve general-use transducers; for example, strain gauges exclusively for general-use transducers have been developed.

Civil engineering and construction transducers

These transducers are designed to meet the needs of customers in civil engineering and construction, that is, to ensure long-term stability under rigorous measurement conditions. The full lineup and quality of these transducers are highly regarded in this sector of industry where general versatility and functionality of equipment and machinery are considered particularly important. Transducers designed for specific work methods or work types are also available.

Measuring instruments

These are special-purpose measuring instruments required when conducting measurement activities using strain gauges or strain-gauge-type transducers. Many types of measuring instruments are provided, as in the case of data loggers, dynamic strain measuring instruments, histogram recorders, and other TML measuring instruments. TML selects measuring instruments with consideration of objects of measurement, required data, operating environments, etc., and makes the most of their characteristics and performance when making measurement.

Measurement software

In making measurement, computers are used to process data and to perform central control of a measurement process using online communication techniques. TML has developed many measurement software programs to achieve speed and accuracy in measurement, considering that software is a key to computerization of measurement activities. TML uses many software programs developed specifically for measurement, management of construction operations, open experiments, etc. In addition to Visual LOG measurement software that can be used for all types of objects of measurement, TML also works on the development of new software for specific measurement projects on a commission contract basis.

TML's high-quality products are the results of quality management and quality assurance activities

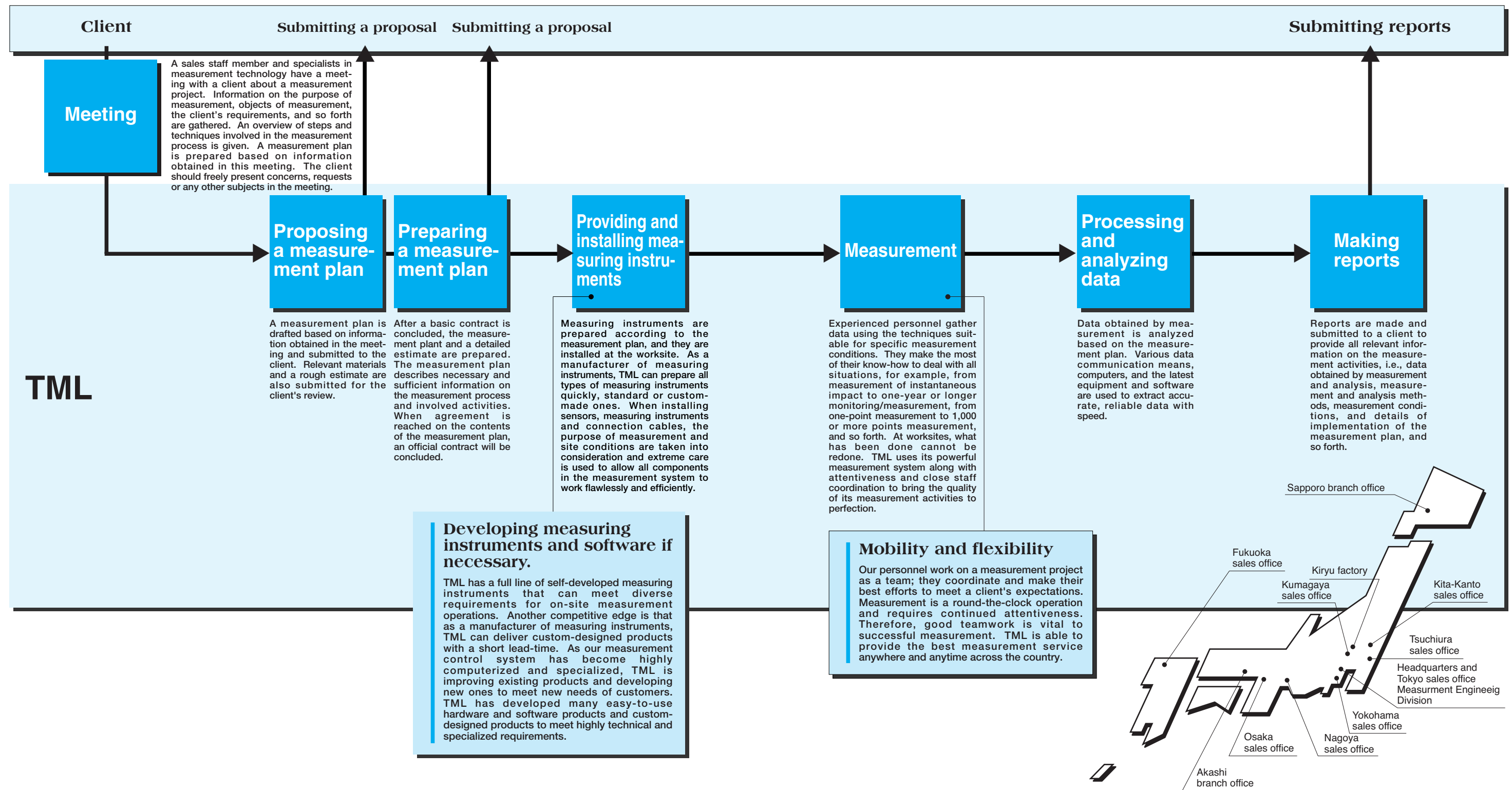
TML, an all-around manufacturer of strain gauges and other measuring instruments, yields high-reliability products from a quality management system working in all stages of manufacturing activities from product development to manufacturing to inspection. Strain gauges are inspected in accordance with the NASA specification NAS942. TML is now working to build a quality assurance system that conforms to the ISO 9000 series*. Reliability of measurement can be ensured only if the quality of measuring instruments has been enhanced to the level where accurate data can be obtained at all times under any conditions. TML's quality products are the basis on which effective, efficient measurement consulting services can be provided.

* The design and manufacture of TML strain gauges, strain measuring equipment and transducers has gained ISO9001 accreditation.



TML Proposes a Measurement Process Best Suited for a Client's Needs and Conditions

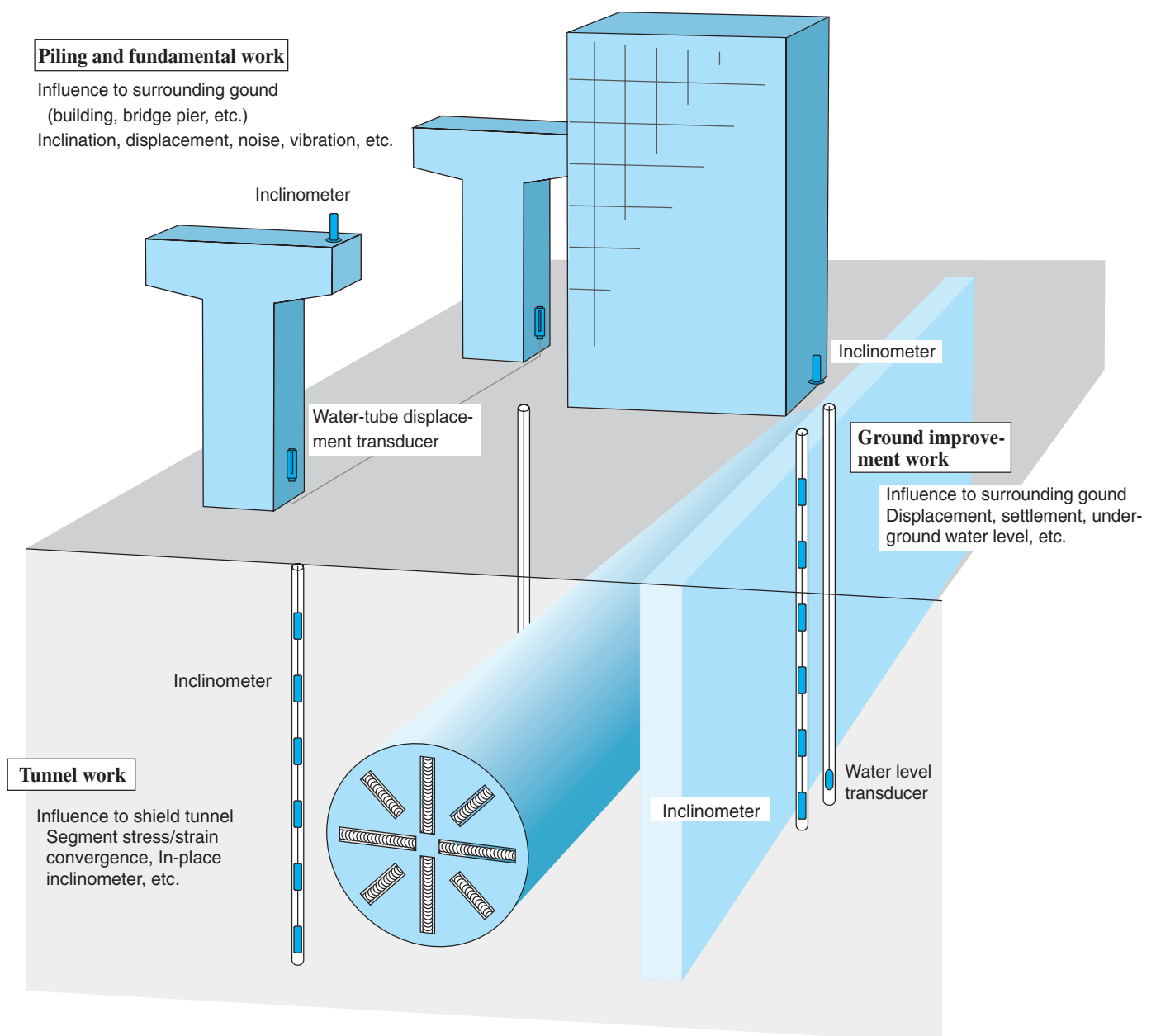
Measurement is a key to successful execution of civil engineering and construction work in all stages from testing to work management. Although the importance of measurement is recognized, work operators face the challenge of acquiring reliable data with limited time and cost. TML has a quick grasp of a client's purpose of measurement, site conditions, and the standing of measurement activity in overall project activities, and proposes and implements a necessary and sufficient measurement plan. TML proposes the most appropriate approach to measurement so that a client can perform measurement operations in all steps of a measurement process with the highest level of efficiency and obtain reliable data.



TML proposes a management and measurement system to achieve more efficient measurements through the use of information and communication equipment.

The rationalization of long-term ageing measurement, dynamic behavior monitoring and construction and maintenance management measurements leads to reduction of labor and facility maintenance costs. By introducing not only Internet technology and the latest information communication technology but conventional technology in data transfer to a control or monitor room for centralized control of a remote area and multiple locations and building up the optimum system according to measurement environments, unmanned and automatic operation in measurement process and rationalization and high efficiency of a remote distance communication system can be materialized to reduce the maintenance cost.

■ Examples of neighboring construction measurement



Construction Management and Dynamic Behavior Monitoring System

■ Features

- Planning of measurement system according to field measurement environments
- Correspondence to various communication system
- Possible setup of automatic alarming and communication
- Possible centralized control and automatic monitoring

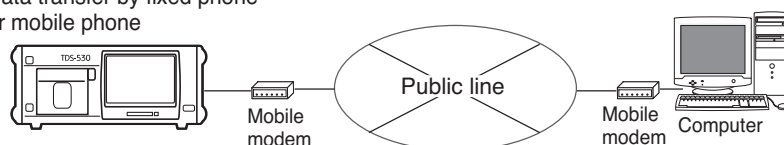
Measurement system with telecommunication network

Data transfer by mobile phone



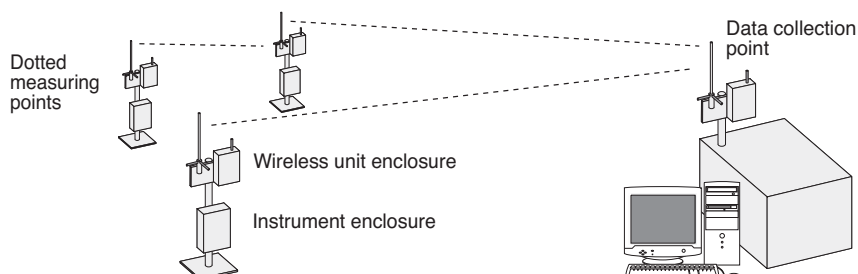
Measurement system with telecommunication network

Data transfer by fixed phone or mobile phone



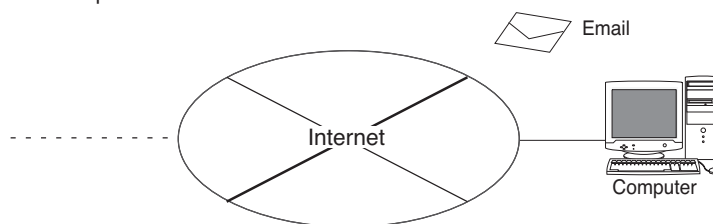
Wireless measurement system

Data transfer by fixed phone, effective in a place such as mountains where public line or mobile phone is not available.



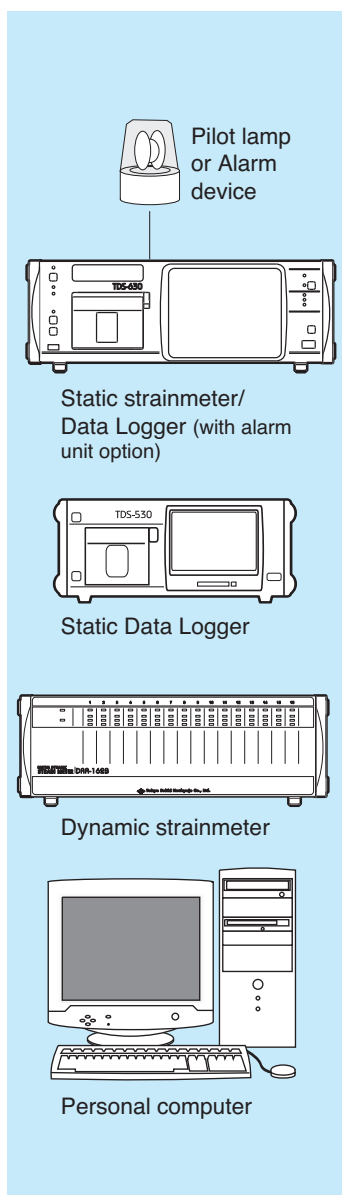
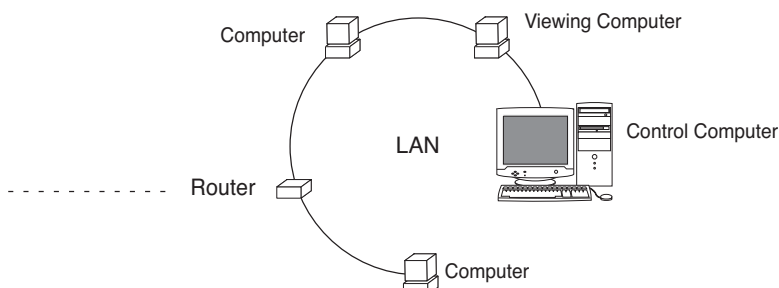
Measurement system by Internet communication

Data distribution by Web server or email as well as direct control is possible.



Measurement system by LAN

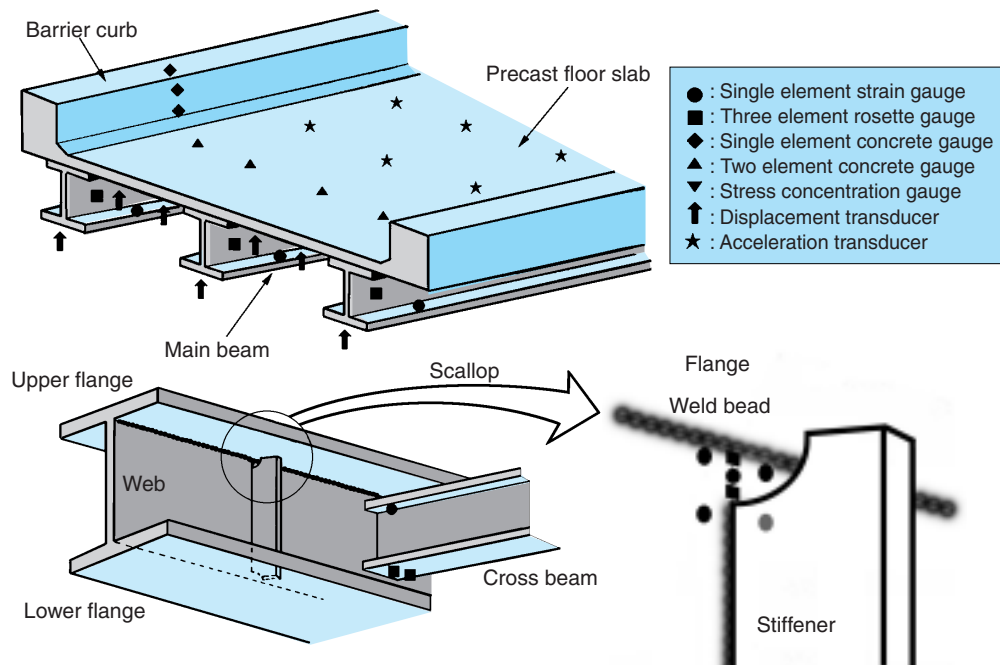
Data transmission by fiber optics, wireless LAN or VPN



1 Bridge measurement

Measurement Management of Steel Beam Bridge

Steel beam bridge measurement is divided into four categories: static loading measurement, dynamic loading measurement, frequency measurement and vibration measurement. In the static loading measurement, the status of the generation of static stress using a test car is seized, and in the dynamic loading measurement, that of dynamic stress during a test car or ordinary car passing is observed. In the frequency measurement, the degree of fatigue affecting a steel bridge is measured. In the vibration measurement, data are collected using a constant tremor method, exciter method, vehicle stop/go method and so on, and vibration mode is identified by FFT and modal analysis of the collected data.



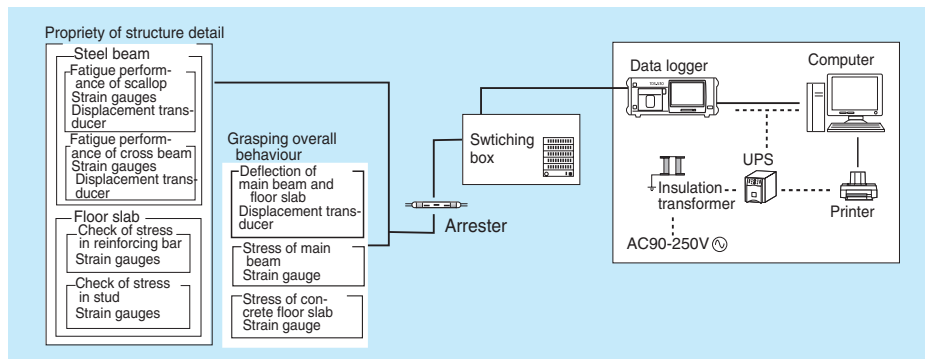
A list of Measuring Instruments

Measurement items	Instruments	Type	Description
Main beam strain	Single strain gauge	FLA	Measures strains in flange axial direction.
	3-element rosette gauge	FRA	Measures principal strains of web and its direction.
Main beam displacement	Displacement transducer	CDP, OU	Monitors deflection of main beam
Stiffener strain	Single strain gauge	FLA	Measures strains in stiffener axial direction.
	3-element rosette gauge	FRA	Measures principal strains of stiffener and its direction.
Cross beam strain	Single strain gauge	FLA	Measures strains in axial direction of stiffener
	3-element rosette gauge	FRA	Measures principal strains of cross beam and its direction.
Scallop strain	Stress concentration gauge	FXV	Measures stress concentration strains of weld part
	Single strain gauge	FLA	Measures strains in scallop axial direction.
	3-element rosette gauge	FRA	Measures principal strain of scallop and its direction.
Floor slab strain	Single strain gauge	PL	Measures strains in floor slab axial direction.
	2-element cross gauge	PLC	Measures principal strains of floor slab.
Barrier curb strain	Single strain gauge	PL	Measures strains in barrier curb axial direction.
	2-element cross gauge	PLC	Measures principal strains of barrier curve.
Floor slab deformation	Displacement transducer	CDP, OU	Monitors deflection of floor slab.
	2-directional crack gauge	KG-B	Measures X and Y of crack opening displacement of an object.
	3-directional crack gauge	Custom	Measures X, Y and Z of crack opening displacement of an object.
Vibration of floor slab	Acceleration transducer	ARF-A	Monitors waveform from a test by the methods of constant tremor, exciter, vehicle stop/go and falling weight
	Servo accelerometer	Other maker	Monitors waveform from a test by the methods of constant tremore, exciter, vehicle stop/go and falling weight.
Temperature	Thermocouple, Temperature gauge	T, KT-A	Measures temperatures of bridge members

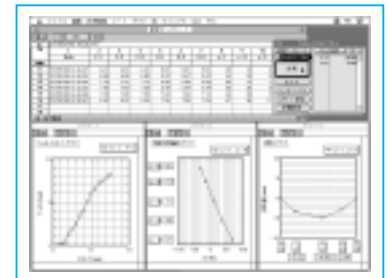
Measurement Management of Steel Beam Bridge

Static measurement

Steel beam bridge static measurement system block diagram

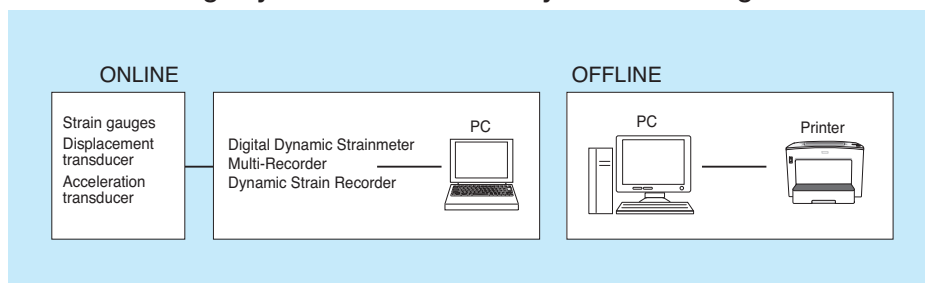


Static measurement display screen

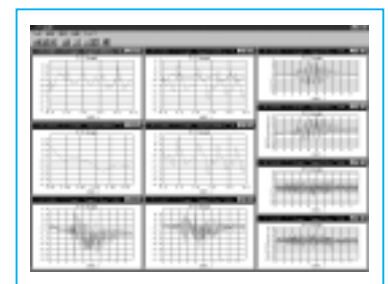


Dynamic measurement

Steel beam bridge dynamic measurement system block diagram

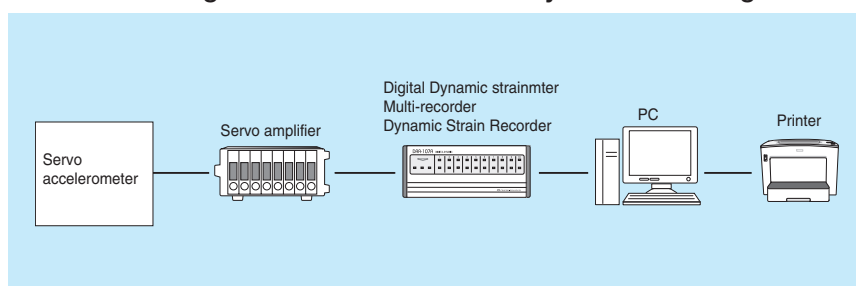


Dynamic waveform data

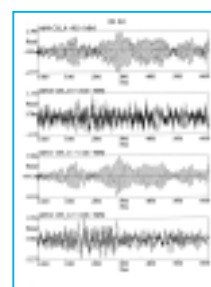


Vibration measurement

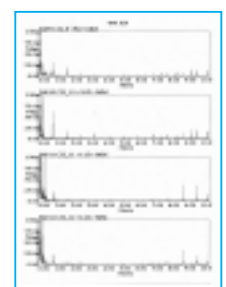
Steel beam bridge vibration measurement system block diagram



Waveform data

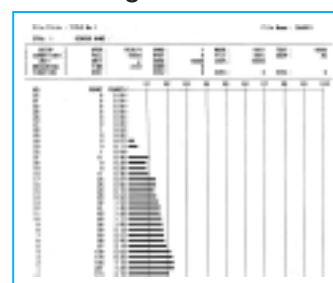
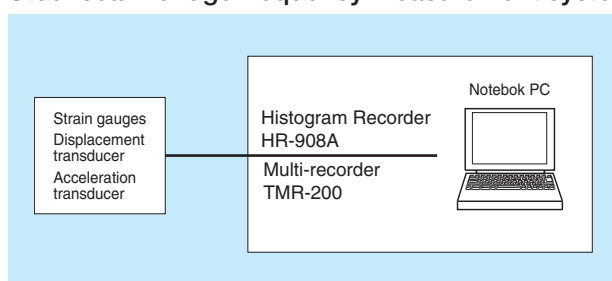


FFT



Frequency measurement

Steel beam bridge frequency measurement system block diagram



Frequency data graph

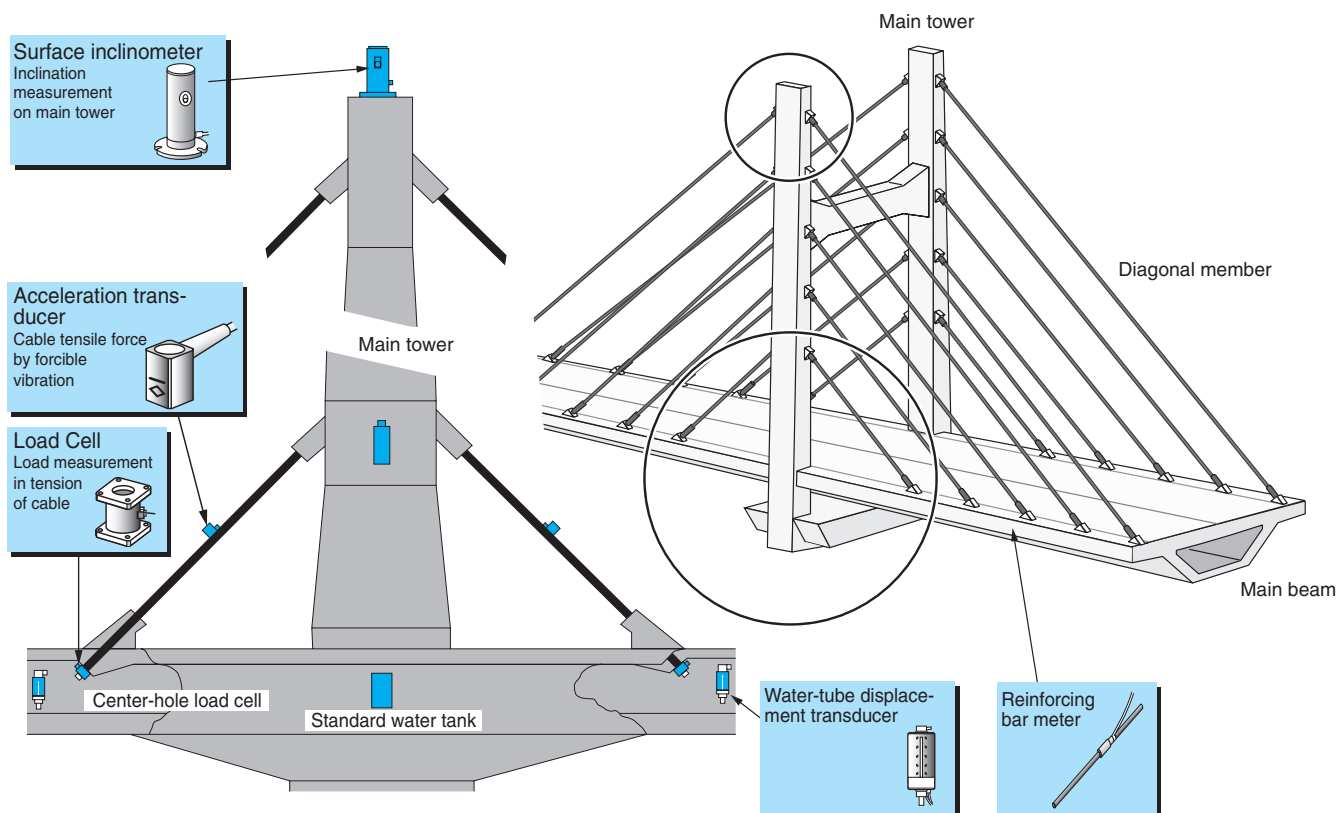


Frequency data list

1 Bridge measurement

Measurement Management of Cable-stayed Bridge

When constructing a PC (pre-stressed concrete) cable stayed bridge, the following conditions must be monitored and controlled: (1) Inclination of a main tower, (2) Materials (concrete, PC grout, etc.) quality, (3) Deflection (camber and shape), (4) Tensile force of diagonal members and (5) Tension of PC steel members. Design values (tensile force of diagonal members, temperature of members, deflection of a main beam, stress, etc.) are provided as a set of work execution management values. Work is executed and controlled by checking the work execution management values against values obtained by making actual measurement.

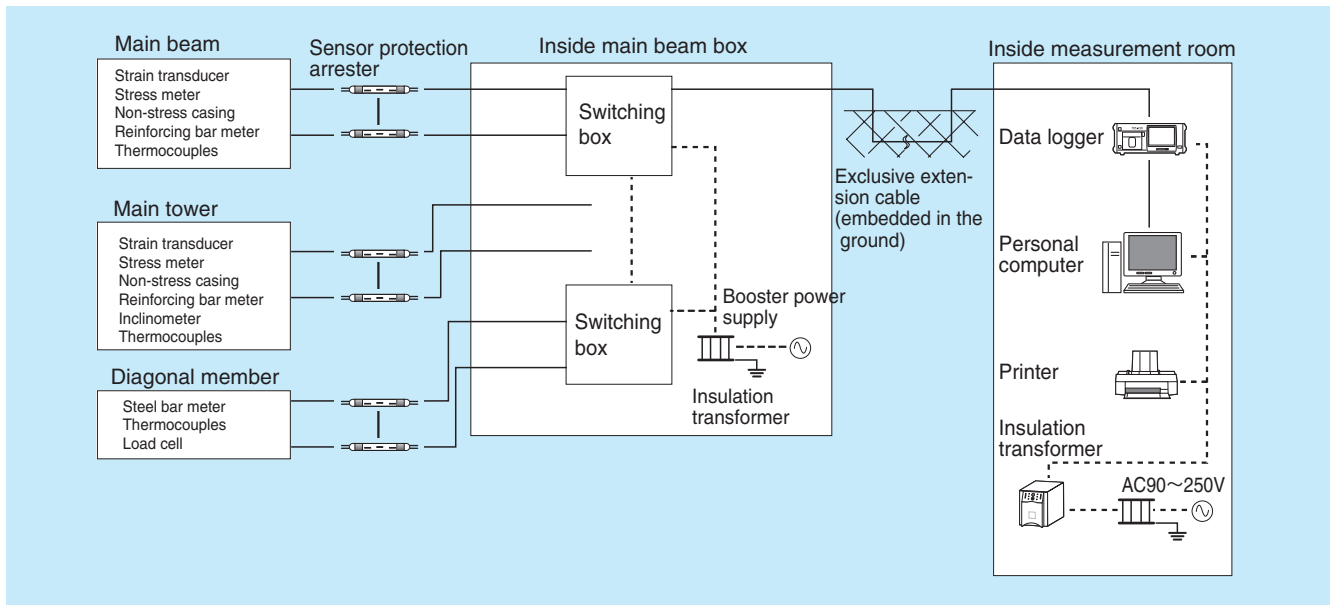


A list of Measuring Instruments

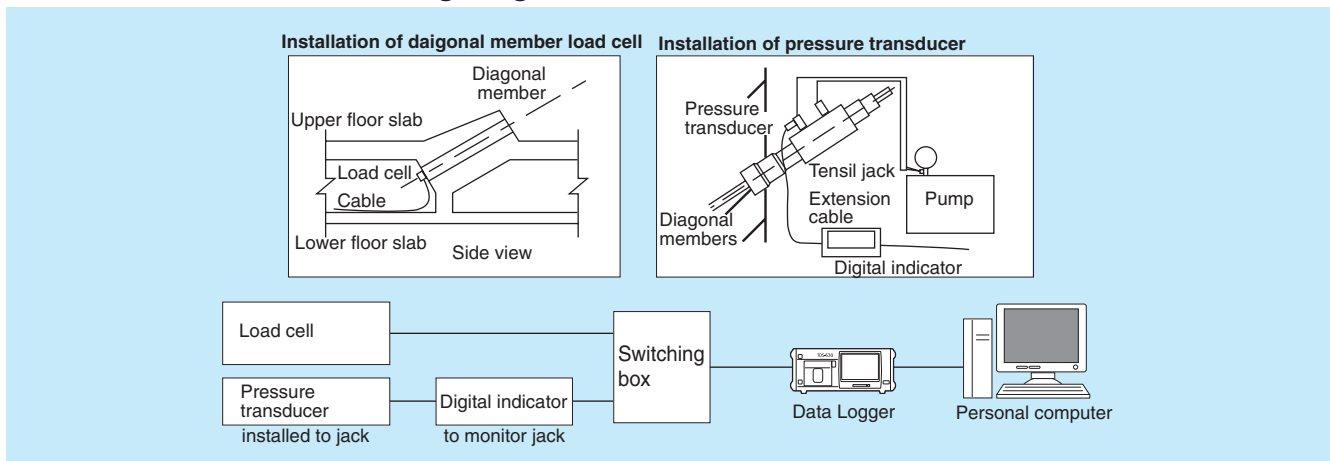
Measurement items	Instruments	Type
Concrete strain	Strain Transducer	KM-A, KM-AT, KM-B, KM-BT
Concrete dry shrinkage	Non-stress casing	KM-B, KM-BT, KM-KMF
Reinforcing bar stress	Reinforcing bar meter	KSA-A, KSAT-A
Pre-stressed introduction force of main tower	Center-hole load cell	KCM-NA, KCE-NA, KCG-NA
Main tower inclination	Surface inclinometer	KB-AB, KB-AC, KB-DB, KB-EB
Tensile force of diagonal members	Center-hole load cell	KCM-NA, KCE-NA, KCG-NA
Tensile force of jacks	High capacity pressure transducer	PWH-PA
	Center-hole load cell	KCM-NA, KCE-NA
Temperature	Thermocouple, Temperature gauge	T, KT-A
	Temperature-integrated strain transducer	KM-B, KM-BT
Tensile force of diagonal members by forcible vibration	Acceleration transducer	ARF-A
Concrete stress	Stress meter	Other products
Deflection of main tower	Water-tube displacement transducer	KWL-B, KWL-E
	Electronic level staff	Other products

Measurement Management of Cable-stayed Bridge

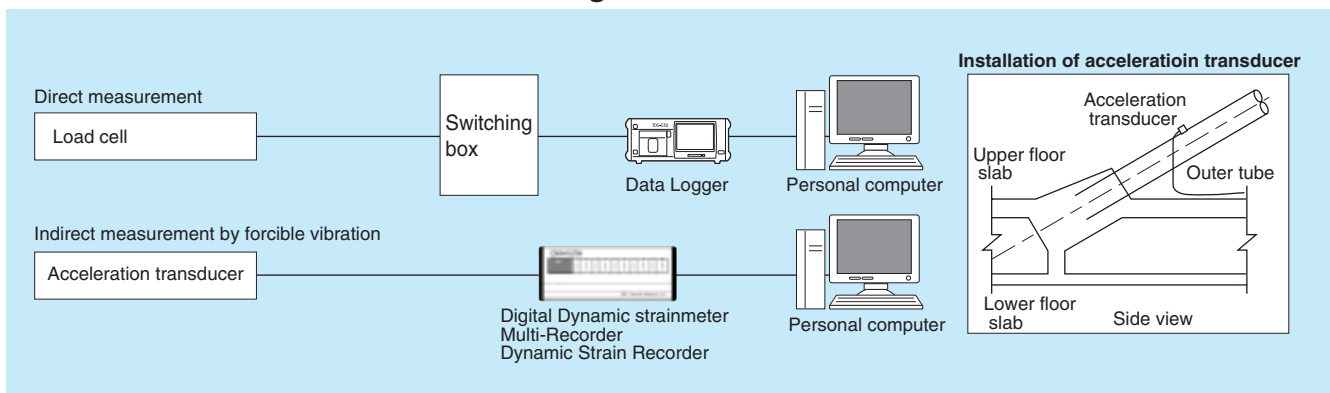
Measurement System Block Diagram



Measurement in stretching diagonal members

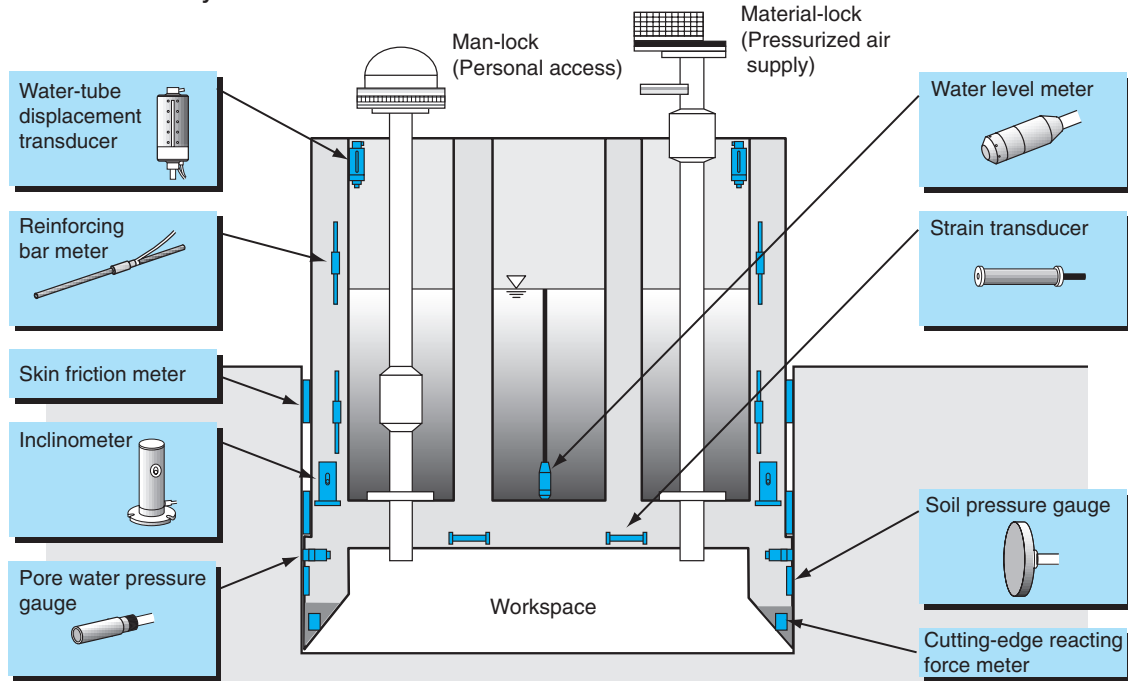


Measurement of tensile force of diagonal members



2 Caisson measurement

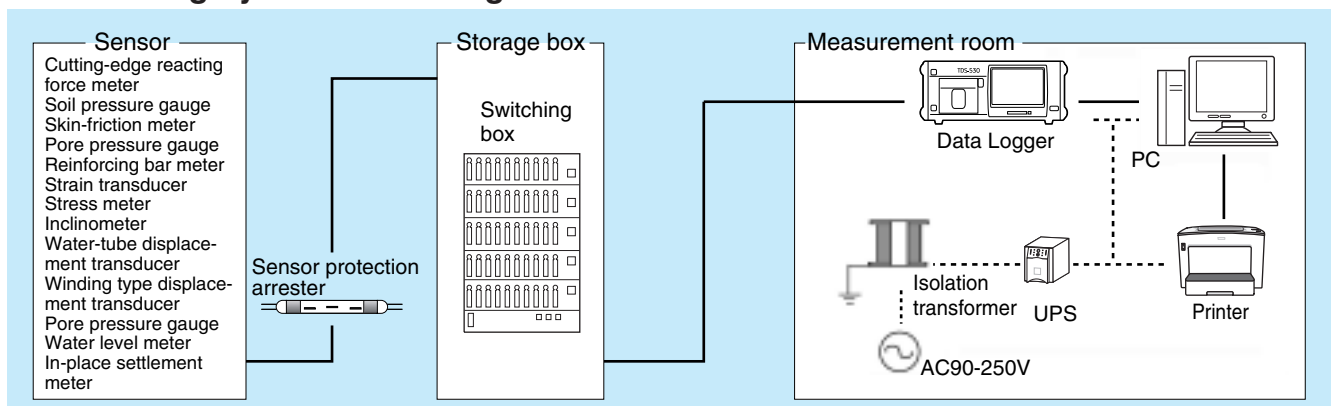
When installing a caisson, the following conditions must be monitored and controlled to gather data on the degree of sinking of the caisson body:



A list of Measuring Instruments

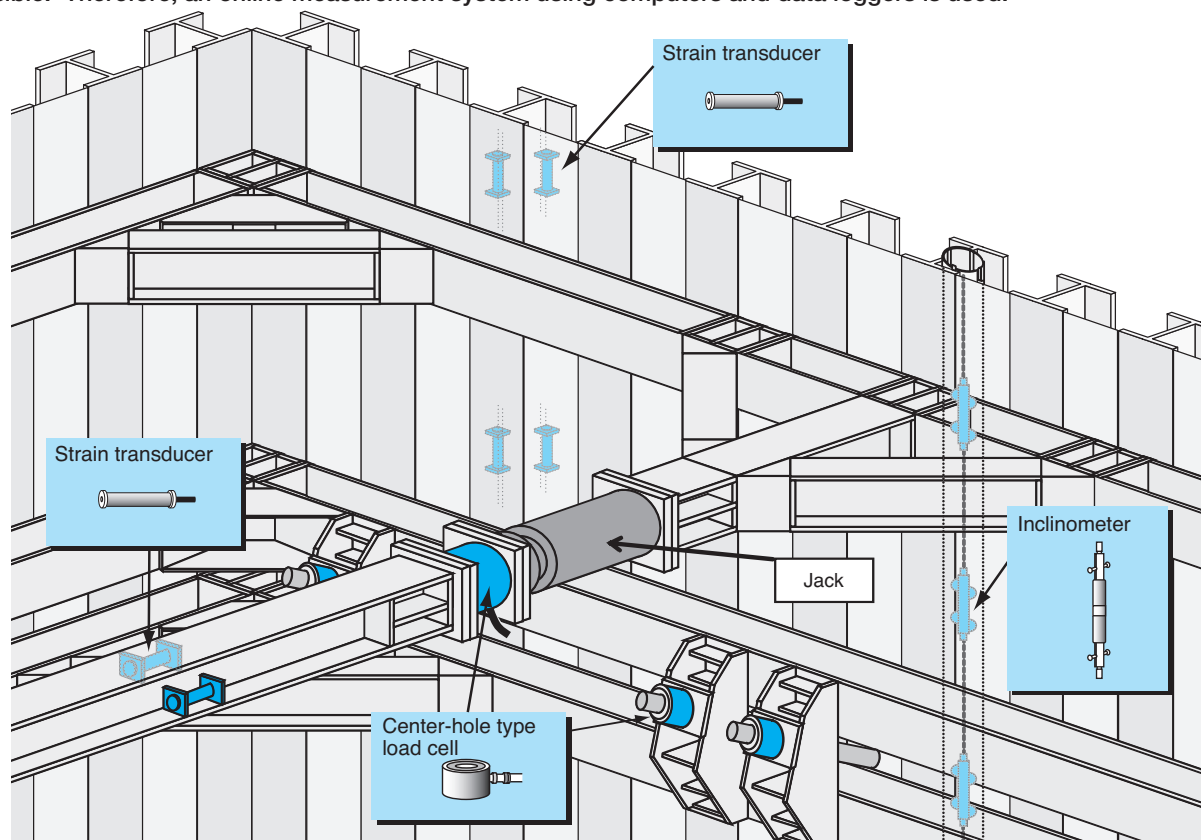
Measurement items	Instruments	Type	Description
Cutting-edge reacting force	Cutting-edge reacting force meter	KKB-PA	Finds reaction force by embedding a load cell in the cutting edge
Soil pressure on wall	Soil pressure gauge for wall surface	KDB-PA KDD-PA	Hollows out in a box shape on the side face of a caisson and fixed thereto.
Skin-friction	Skin-friction meter	KKA-PA	Hollows out in a box shape on the side face of a caisson and fixed thereto.
Pore pressure of the surroundings	Pore pressure gauge	KPA-PA KPC-PA	Hollows out in a box shape on the side face of a caisson and fixed thereto.
Behavior within the caisson	Re-inforcingbar meter Strain transducer Stress meter	KSA-A, KSAT-A, KM-B KM-BT, Other maker	Pressure-welds to a re-bar inside a caisson wall to measure stress. Measures strain inside the wall. Fix a stress meter inside to measure an effective force of a concrete.
Inclination	Inclinometer	KB-AB, KB-AC	Fixes it to a point of interest to find the attitude of a caisson from tilt angles of X and Y components.
Subsidence of caisson	Water-tube displacement transducer	KWL-B KWL-E	A reference water tank is fixed inside the caisson and relative sinking amount is found from the transducers connected via water tube.
	Winding type displacement transducer	DP-E	The sinking amount of a caisson to the ground level is measured.
Atmospheric pressure within the caisson	Pore pressure gauge	KPA-PA KPC-PA	One method is the use of absolute pressure and another the back pressure of a relative pressure transducer made open to atmospheric pressure outside the caisson.
Weight of water	Water level meter	KW-C	Found by measuring water level inside the caisson.
Settlement of surrounding ground	In-place settlement meter	KLA-A, NKLA-A KLC-A	The sinking amount of a settlement plate placed on the ground level to a fixed point which is an anchor of measuring rod.
Temperature	Thermocouple thermometer	T, KT-A	Measures temperature inside and outside the caisson.

Measuring System Block Diagram



3 Retaining Wall measurement

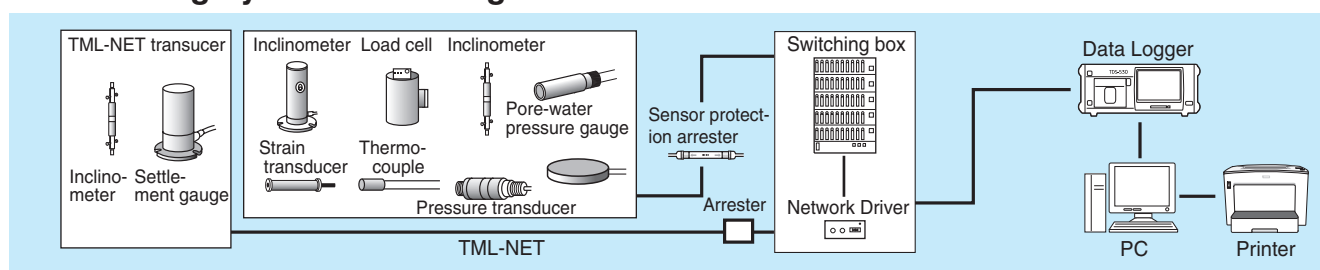
Conditions to be monitored when constructing retaining walls include subsidence, movement and displacement of ground, groundwater conditions, lateral pressure on earth retaining walls, deformation and pressure conditions of earth retaining structures, and so forth. The collapse of retaining walls, effects of collapse on surrounding ground, heaving, boiling, and other dangerous phenomena must be detected and necessary actions must be taken as quickly as possible. Therefore, an online measurement system using computers and data loggers is used.



A list of Measuring Instruments

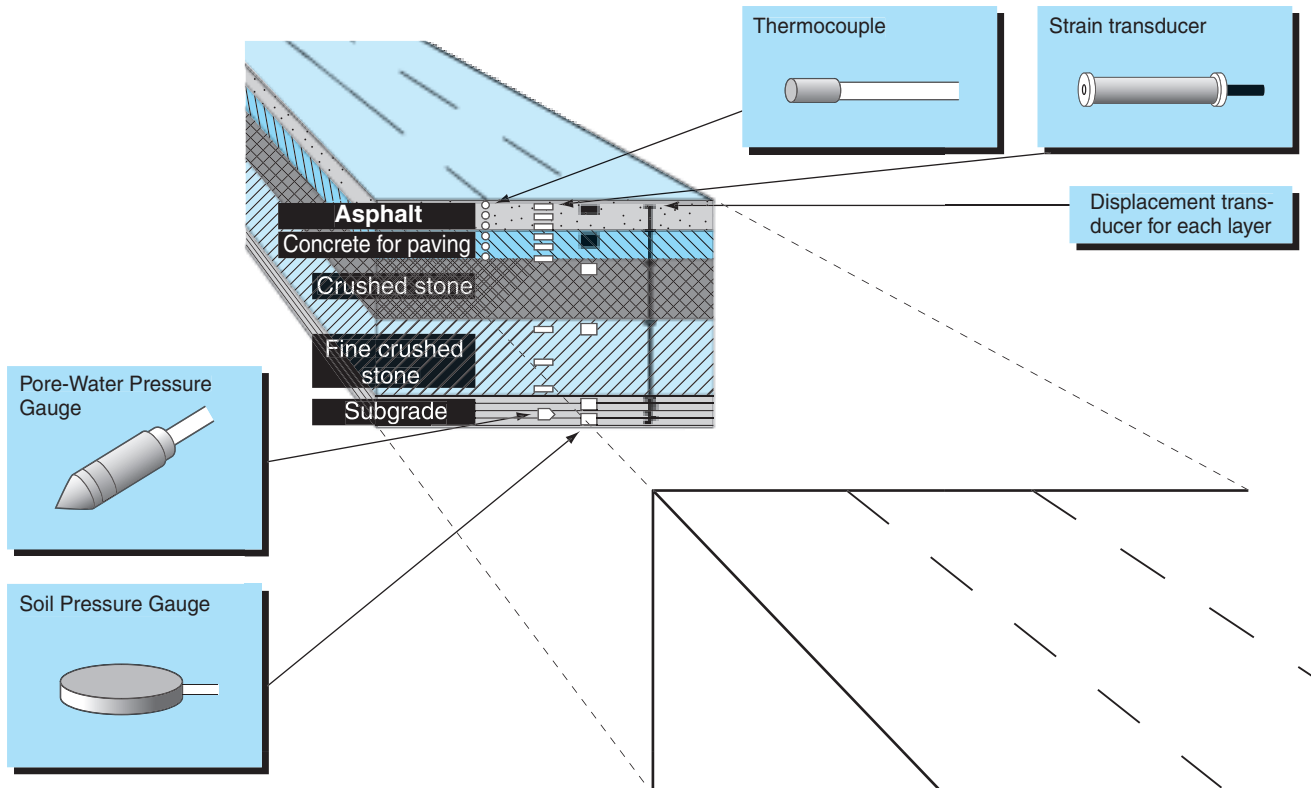
Object of measurement	Measurement items	Instruments	Type
Earth retaining wall	Lateral pressure	Soil pressure gauge	KDB-PA, KDD-PA, KDF-PA
		Pore water pressure gauge	KPA-PA, KPB-PA
	Deformation and stresses of wall	Strain transducer	KM-B
		Reinforcing bar meter	KSA-A, KSAT-A
		Inclinometer probe	KB-GC, KB-HC
		Surface inclinometer	KB-DB, KB-EB, KB-AB, KB-AC
		In-place inclinometer	KB-JE, KB-KE, NKB-LD, NKB-MD
		Thermocouple	T
		Center-hole type loa cell	KCM-NA, KCE-NA
		Pressure transducer	PWH-PA
		Center-hole type loa cell	KCM-NA, KCE-NA
	Axial force of strut	Strain transducer	KM-B, KM-BT
Strut	Strains of strut	Thermocouple, Temperature gauge	T, KT-A
	Temperature	Strain transducer	KM-B
Waling	Stress of waling	Strain transducer	KM-B
Cutting bottom	Heave of ground at bottom	Ground displacement transducer	KLA-A, NKLA-A
	Underground water level	Water level meter	KW-C
	Pore pressure	Pore water pressure gauge	KPA-PA, KPB-PA
Surrounding ground	Settlement	Ground displacement transducer	KLA-A
	Lateral displacement	Inclinometer probe	KB-GC, KB-HC
		In-place inclinometer	KB-JE, KB-KE, NKB-L, NKB-MD
	Underground water level	Water level meter	KW-C
	Settlement	Water tube displacement transducer	KWL-E
Surrounding structure	Inclination	Surface inclinometer	KB-AB, KB-AC, KB-DB, KB-EB
	Crack	Crack displacement transducer	KG-A

Measuring System Block Diagram



4 Test Pavement measurement

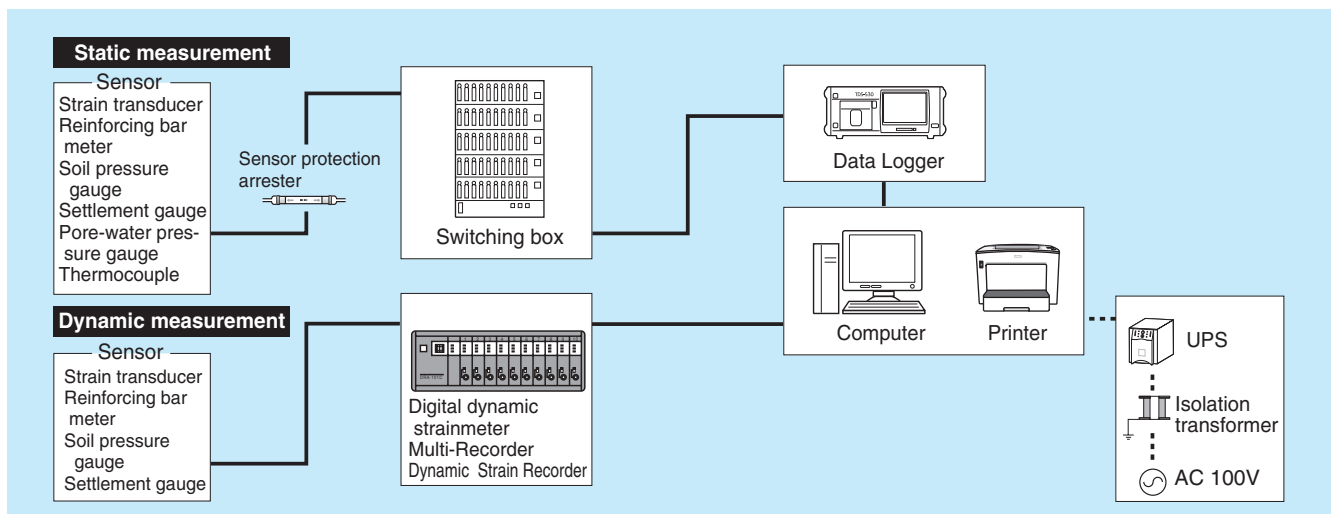
During pavement construction, driving tests, loading tests, and long-period deterioration tests are conducted using various types of sensors to check the degree of fatigue in relation to the load bearing capacity.



A list of Measuring Instruments

Measurement items	Instruments	Type	Description
Soil pressure of subbase course	Soil pressure gauge	KDA-PA, KDC-PA, KDL-PA	Measures soil pressure of each layer.
Strain of pavement body	Strain transducer	KM-B/-BS1/-HBS2	Measures strains after curing and also in curing process.
Settlement of each layer	Displacement transducer for each layer	To order	Installs a settling plate on the top of each layer and measures a relative displacement between each layer.
Pore pressure of subbase course	Pore pressure gauge	KPB-PA, KPD-PA	Embedded in subgrade and measures pore pressure.
Temperature of pavement	Thermocouple Temperature gauge	T KT-A	Measures inside and outside temperature.
Strain distribution of pavement	Surface strain gauge	SSM-360	Measures distribution of strains generated on the surface.

Measurement System Block Diagram

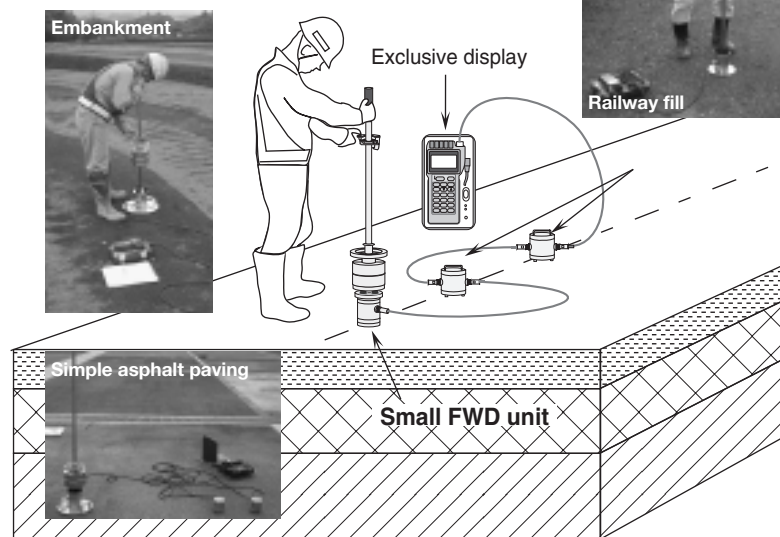


5 Falling Weight Deflectometer FWD

TML small FWD system "FWD-Light®" is a testing device applicable for management and rigidity evaluation of soil structures such as a fill, cut, subbase course and subgrade. As it is easy-to-handle and portable and can measure subgrade reaction coefficient "K" and subgrade elastic modulus "E" in a short period of time, real time feedback to construction site is possible. It can also be used for bearing capacity measurement and rigidity evaluation of asphalt pavement, interlocking block pavement and so on. The testing is conducted according to the methods introduced in the "FWD and Portable FWD Handling Manual (2003.1)" issued by JSCE (Japan Society of Civil Engineers) and "Design Standards for Railway Structures and Commentary" edited by RTRI (Railway Technical Research Institute).

Main Applications

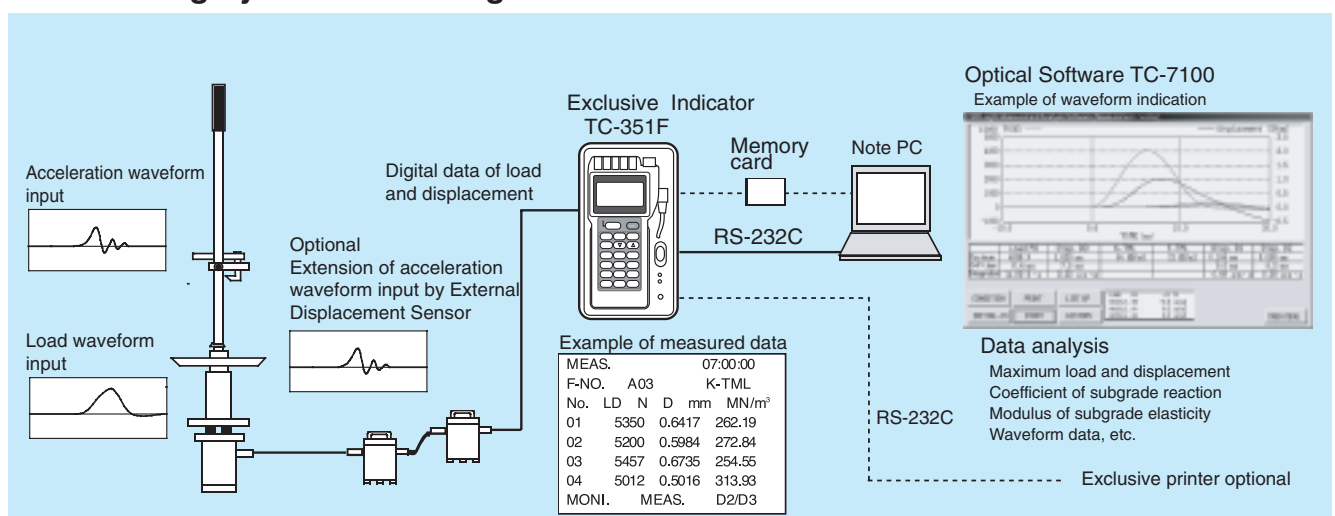
- General ground such as railway fill, subgrade and subbase course
- High rigid ground such as airport
- Refilling soil for buried pipe
- Small asphalt paving
- Interlocking block paving



An example of data sheet creation

Instruments	Type	Brief Specification
Small FWD unit	KFD-100A	Build-in load cell and accelerometer, Max. load: 20kN, Max. displacement: 2.5mm
Exclusive display	TC-351F	Displays max. load, max. displacement, subgrade reaction coefficient and subgrade elastic modulus and records/saves on memory card.
External displacement sensor	KFDS-1B	Built-in accelerometer, max. displacement of 1mm
Measurement/processing software	TC-7100	In addition to analysis result with exclusive display, waveform display of load, acceleration, velocity and displacement and display of O-P time and time accumulation is possible.

Measuring System Block Diagram

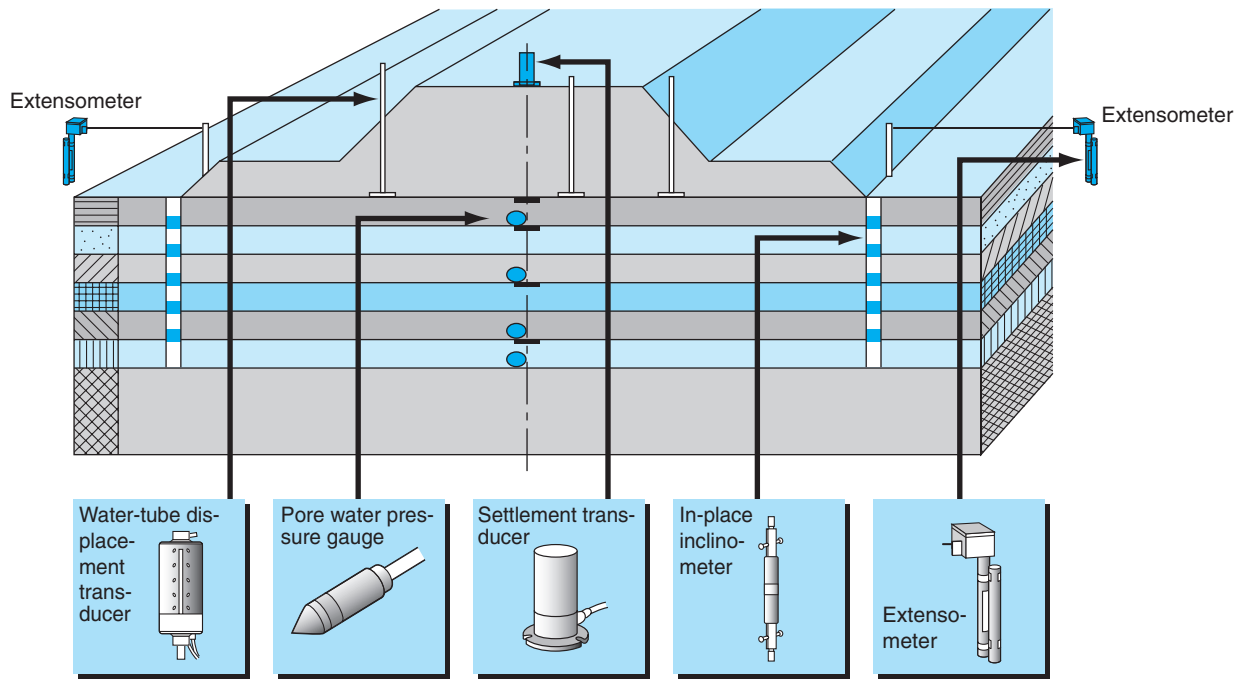


6 Fill Measurement

For filling work on soft ground, the following conditions must be monitored:

- (1) Conditions of ongoing work and the status of process management by performing measurement control operations
- (2) Safety factor or margin of a fill, (3) Critical load and deflection, (4) Amount of subsidence and heaving

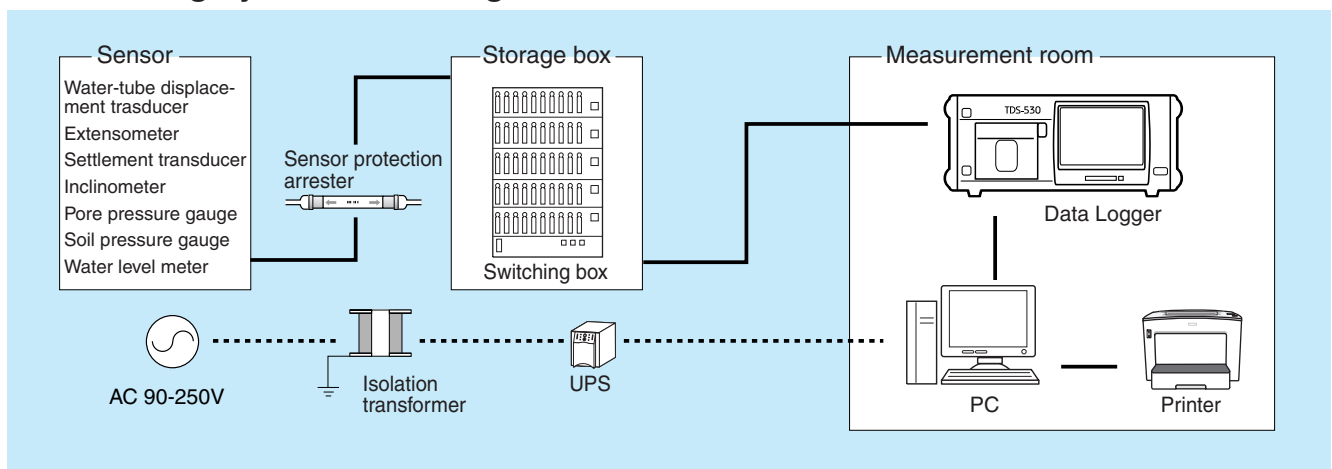
With a computer, a data logger and measuring instruments linked in an online measurement network, conditions of ground subsidence, horizontal displacement, earth pressure in subterranean ground and pore water pressure are monitored so that appropriate action can be taken if any abnormal condition is detected.



A list of Measuring Instruments

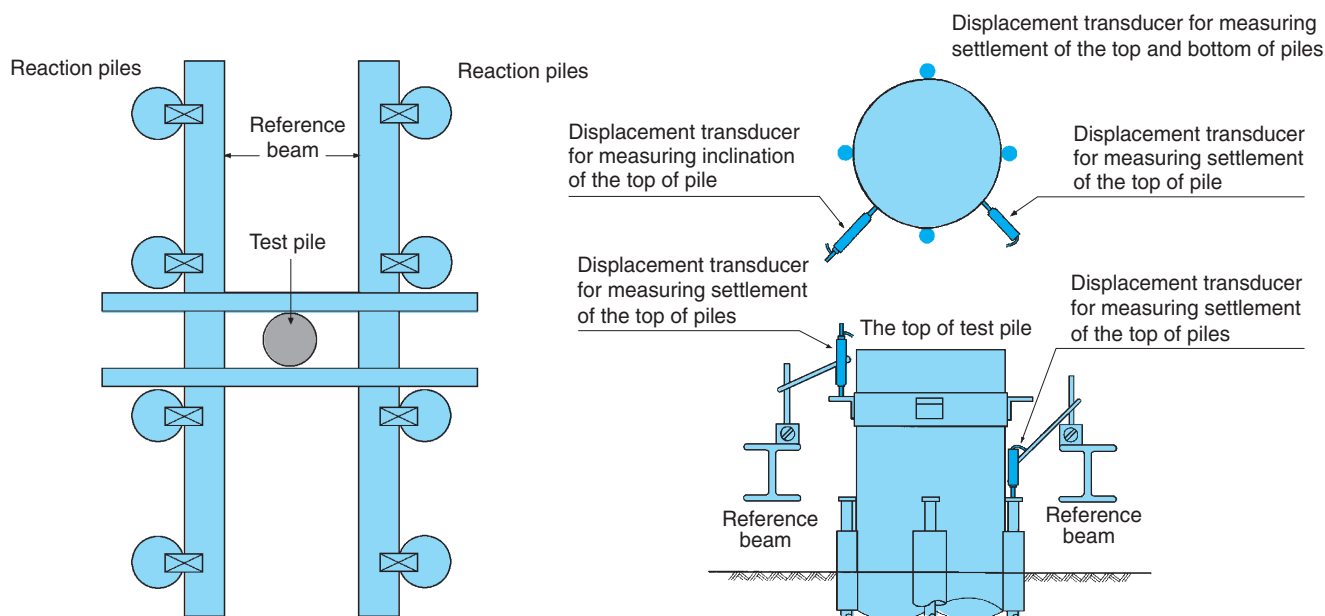
Measurement items	Instruments	Type	Description
Vertical displacement of ground surface	Water-tube displacement transducer	KWL-E	Measures the amount of settlement at the bottom of fill
Horizontal displacement of ground surface	Extensometer	KLG-A, KLG-B NKLG-A, NKLG-B	Measures the amount of horizontal movement.
Vertical displacement of underground	Multi-layer settlement meter	KLA-A, NKLA-A, KLC-A	
Horizontal displacement of underground	In-place inclinometer	KB-JE, KB-KE, KB-JF KB-KF, NKB-LD, NKB-MD	
Pore pressure	Pore pressure gauge	KPB-PA, KPD-PA	
Soil pressure	Soil pressure gauge	KDA-PA, KDC-PA, KDE-PA, KDL-PA	
Water level	Water level meter	KW-C	Particularly when driving a sand compaction pile.
Strain of reinforcing materials	Strain gauge	YFLA	

Measuring System Block Diagram



7 Pile Loading Test Measurement

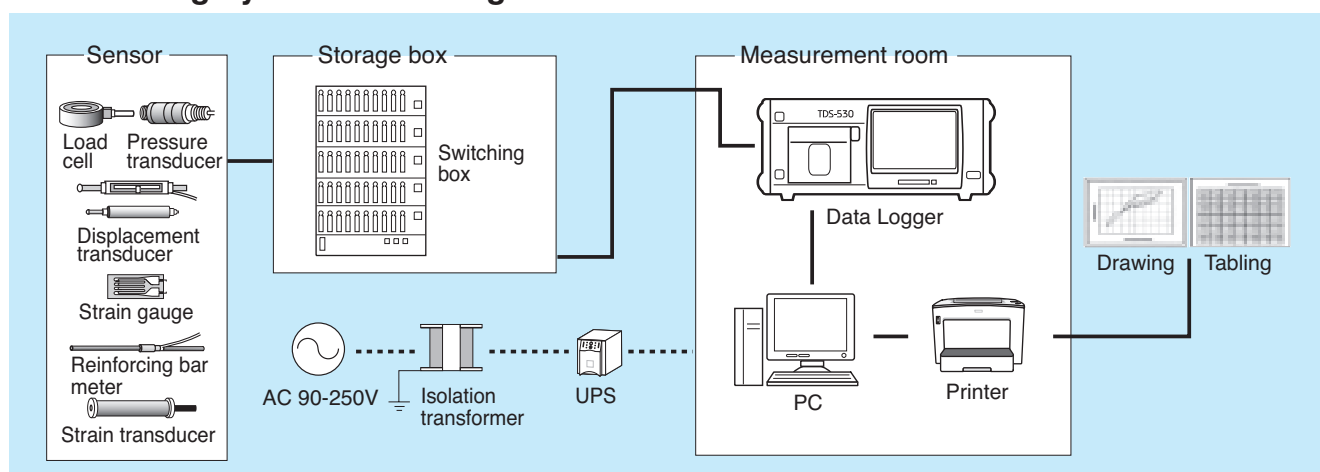
On-site pile measurement includes test measurement to determine design specifications, pile work control measurement during pile work execution, post-execution verification measurement, and follow-up measurement after completion of pile work. It is necessary to build a static and dynamic measurement system suitable for each measurement method, the type of measuring instrument used, the purpose of measurement, and site conditions.



A list of Measuring Instruments

Measurement items	Instruments	Type	Description
Load	Load cell	CLP-NB, CLF-NA	
	Pressure transducer	PWH-PA	
Settlement of pile top	Displacement transducer	CDP	
Settlement of pile bottom	Displacement transducer	CDP	
Horizontal displacement (tilt) of pile top	Displacement transducer	CDP	
Axial strain of pile	Strain gauge	WF	Steel pile
	Reinforcing bar meter	KSA-A, KSAT-A	PC or RC pile
	Strain transducer	KM-A, KM-B	PC or RC pile
Displacement amount of reaction device	Displacement transducer	CDP	

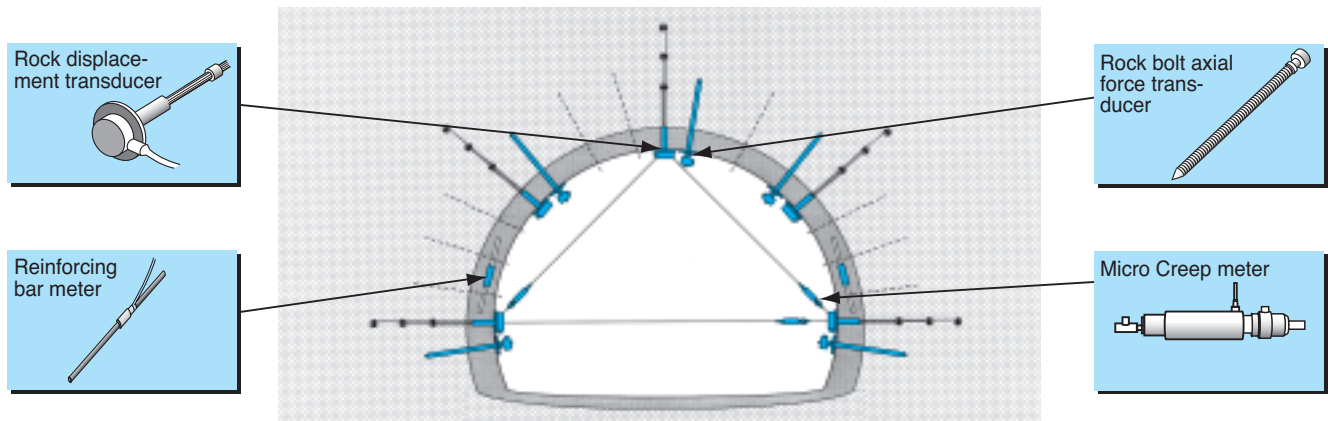
Measuring System Block Diagram



8 Tunnel Measurement

NATM Measurement

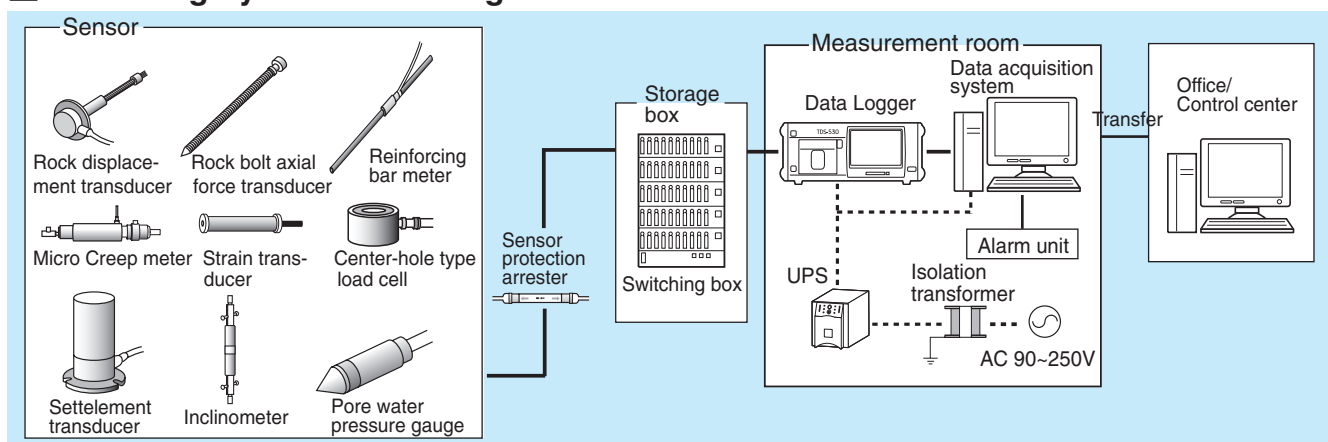
The displacement of surrounding ground and tunnel support structures along with stress conditions are measured during tunnel excavation to ensure work safety and economic efficiency.



A list of Measuring Instruments

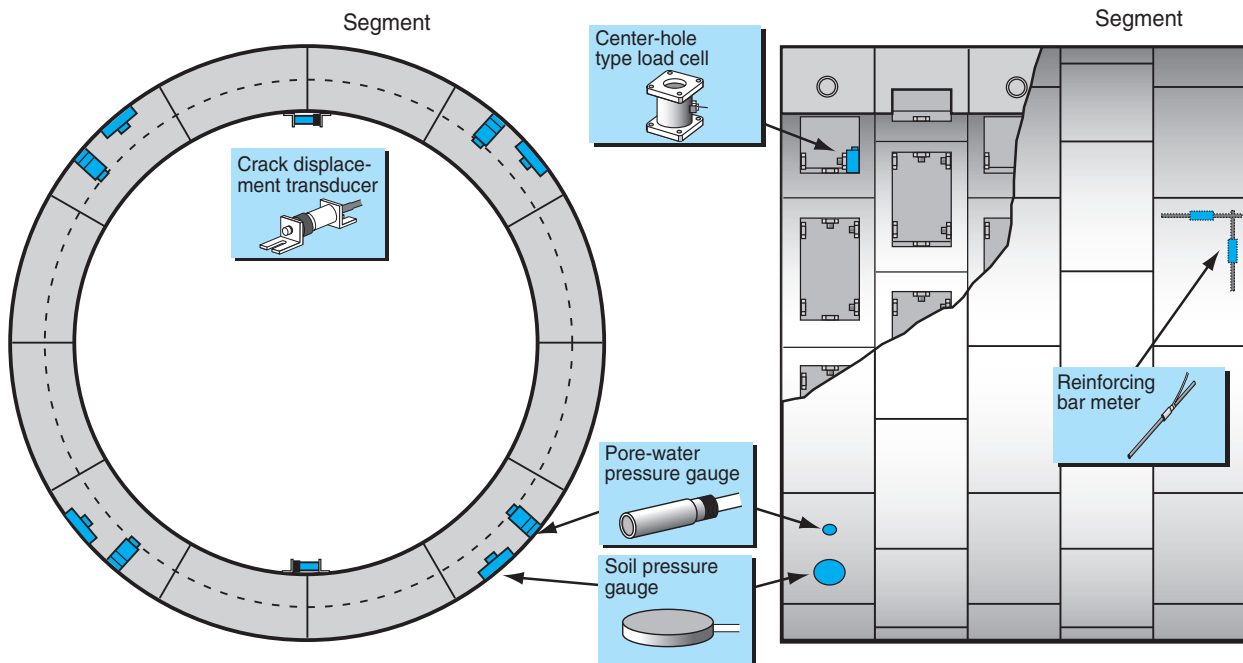
Measurement items			Instruments	Type
Convergence		Change and displacement of distance between tunnel walls	Micro Creep meter	KH-A
Displacement of ground		Horizontal and vertical displacement measured outside the tunnel	Settlement transducer	KLA-A, NKLA-A, KLC-A
			Inclinometer	KB-GC, KB-HC
			In-place inclinometer	KB-JE, KB-KE, NKB-LD, NKB-MD
		Relative displacement in tunnel	Rock displacement transducer	KLB-A
Ground stress	Change of ground stress	Change of stress by excavation	Soil Pressure Gauge	KDB-PA, KDD-PA, KDF-PA
	Pore water pressure	Pore pressure conditions	Pore Water Pressure Gauge	KPA-PA, KPC-PA
Force and stress on support members	Axial force of rock bolt	Force distribution of rock bolt	Rock Bolt Axial Transducer	KRA-A
		Axial force of washer	Center-hole type load cell	CLC-NA, KCM-NA
	Concrete stress	Spraying concrete stress	Strain transducer	KM-A, KM-AT, KM-B, KM-BT
		Stresses of lining concrete	Reinforcing bar meter	KSA-A, KSAT-A
			Strain transducer	KM-A, KM-AT, KM-B, KM-BT
	Stress of steel arch	Stresses of support and members	Strain Gauge	FLA
	Ground load	Ground load on lining	Soil Pressure Gauge	KDB-PA, KDD-PA, KDF-PA
		Back water pressure	Pore Water Pressure Gauge	KPB-PA, KPD-PA
	Effects on surroundings	Behavior of ground surface and structures	Settlement and heave of ground surface	Water-tube Displacement Transducer
Settlement transducer				KLA-A, NKLA-A
Settlement, heave and inclination of structures			Water-tube Displacement Transducer	KWL-E
			Inclinometer	KB-AB, KB-AC, KB-DB, KB-EB
Movement of ground surface			Extensometer	KLG-A, KLG-B, NKLG-A, NKLG-B

Measuring System Block Diagram



Shield Measurement

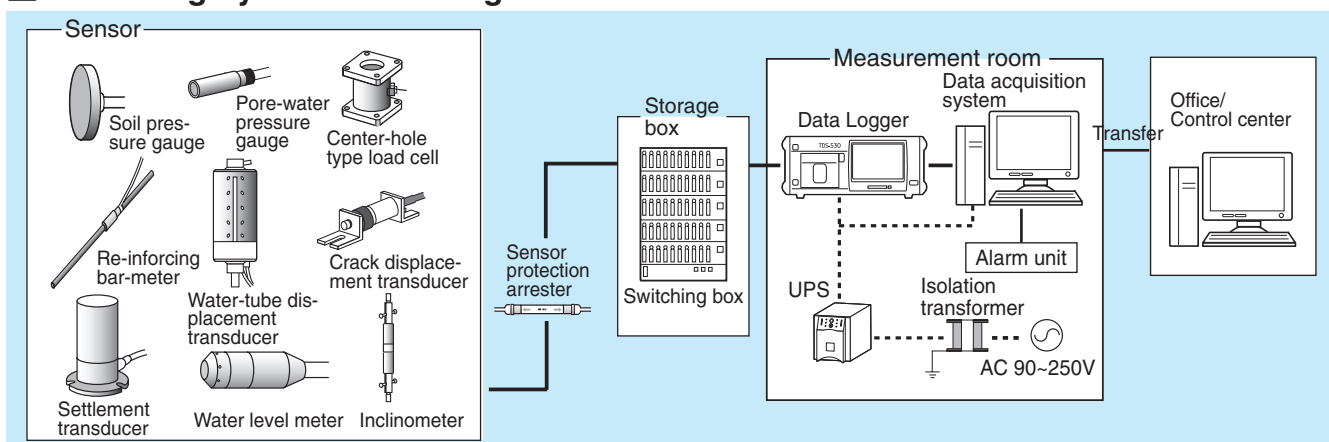
Deformation of segment ring and effects on urban structures are observed.



A list of Measuring Instruments

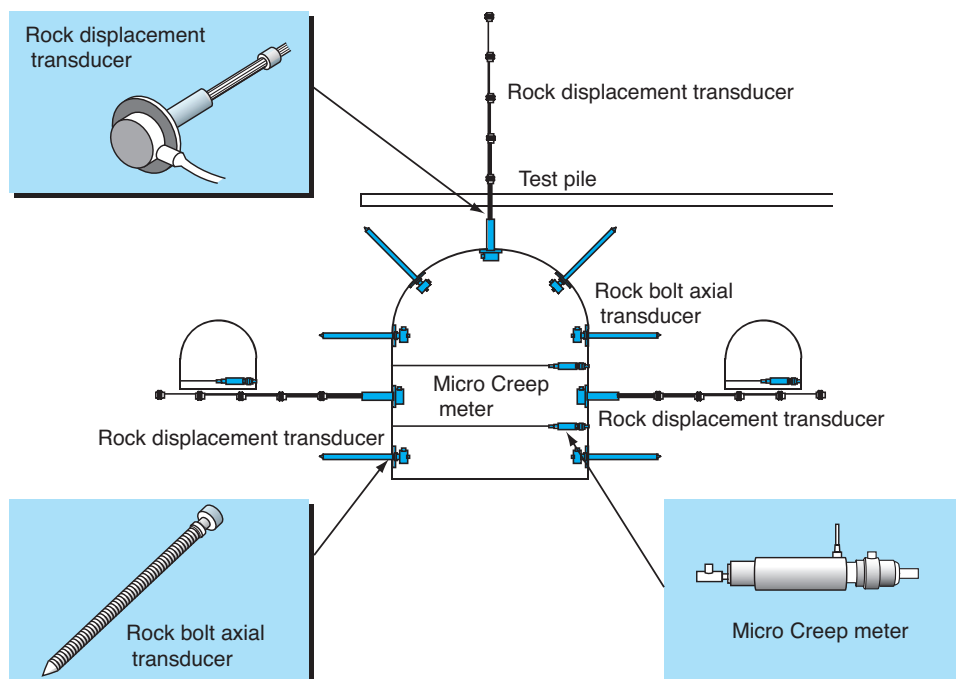
	Measurement items	Instruments	Type
Behavior of segment	Soil pressure acting on the ring	Soil pressure gauge	KDB-PA, KDD-PA, KDF-PA
	Water pressure acting on the ring	Pore-water pressure gauge	KPA-PA, KPC-PA
	Stresses and strains in the ring's rebars	Reinforcing bar meter	KSA-A, KSAT-A
	Deformation of segment joint	Crack Displacement transducer	KG-A
Behavior of ground surface and adjacent structures	Settlement and heave of ground surface	Water-tube Displacement transducer	KWL-E
		Multi-layer Settlement transducer	KLA-A, NKLA-A
	Settlement, heave and inclination of structures	Water-tube Displacement transducer	KWL-E
		Surface Inclinator	KB-AB, KB-AC, KB-DB, KB-EB
	Movement of ground surface	Extensometer	KLG-A, KLG-B, NKLG-A, NKLG-B
	Horizontal and vertical movement of underground	In-place inclinometer	KB-JE, KB-KE, KB-DB, KB-EB, NKB-LD, NKB-MD
	Change in ground water	Water level meter	KW-C
		Pore-water pressure gauge	KPA-PA, KPC-PA

Measuring System Block Diagram



9 Underground Opening Measurement

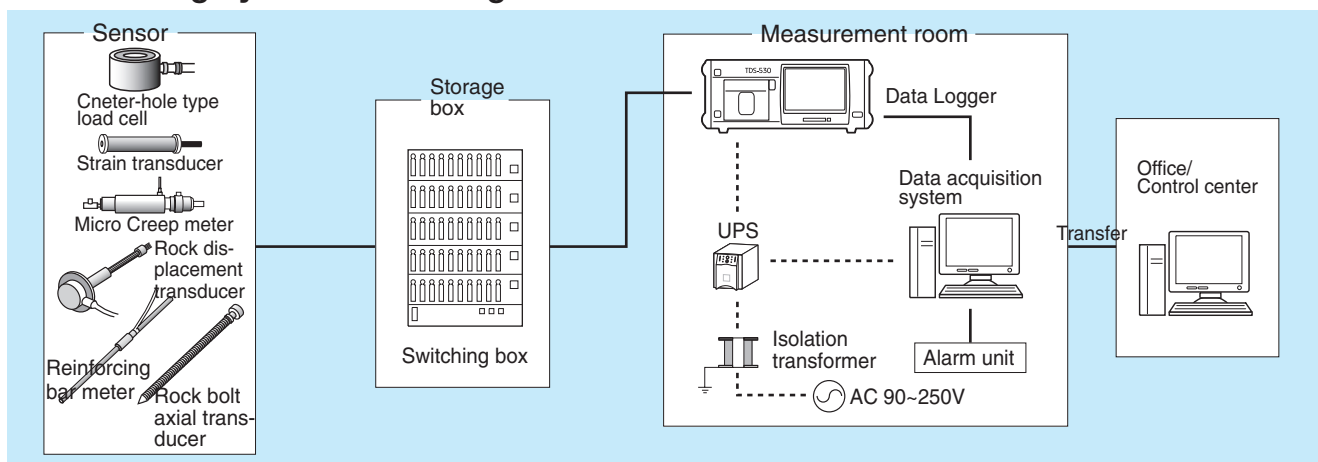
As the cross section of an underground opening becomes large, ground stability decreases and a large-scale support structure is required. The stability of an opening depends on surrounding ground. Since it is very difficult to clarify the level of ground stability by conducting surveys, data on the behavior of ground gathered during construction is analyzed and analysis results are reflected to design and construction. This is an observational construction control system that our company proposes to customers.



A list of Measuring Instruments

Measurement items	Instruments	Type	Description
Displacement of surrounding bedrock (Underground displacement)	Rock displacement transducer	KLB-A	An anchor is fixed in the bore hole, and change of displacement between the anchor and bedrock surface is measured.
Convergence and subsidence of top part	Micro creep meter	KH-A	Measurement pin is fixed on bedrock or concrete surface
	Survey apparatus	Other maker	Measures distance between the pins.
	Electronic distance meter	Other maker	A target is fixed to bedrock or concrete surface to measure an absolute displacement from the reference point.
Load on PS concrete structures	Center-hole type load cell	KCM-NA, KCE-NA	Load cell is installed at the foot of PS structure to measure change of tensile force.
	Rock-bolt axial force meter	KRA-A	Measures rock-bolt axial force.
Stress of arch concrete structures	Reinforcing bar meter	KSA-A, KSAT-A	Installed to arch concrete structures to confirm design strength and time-dependent change of stress and stress distribution.
	Strain transducer	KM-A, KM-AT, KM-B, KM-BT	
	Thermocouple	KT-A, T	
	Non-stress casing	KM-B, KM-BT, KMF	
The amount of spring	Triangular weir water meter	Made to order	

Measuring System Block Diagram



10 Dam Measurement

Fill Dam Measurement

During construction of an earth dam, pore water pressure in the dam body and its foundation ground is measured and data obtained is used to control earth (concrete) filling speeds. Deformation of the dam body and its foundation and the earth pressure on them are also measured during construction. After completion of a dam, the amount of infiltrating water in the dam body and foundation ground and the deformation of the dam body are measured to ensure safe dam operations. In addition, pore water pressure, osmotic pressure on foundation ground, the level of groundwater and so on are measured in order to grasp the state of water infiltration in both the dam body and its foundation ground.

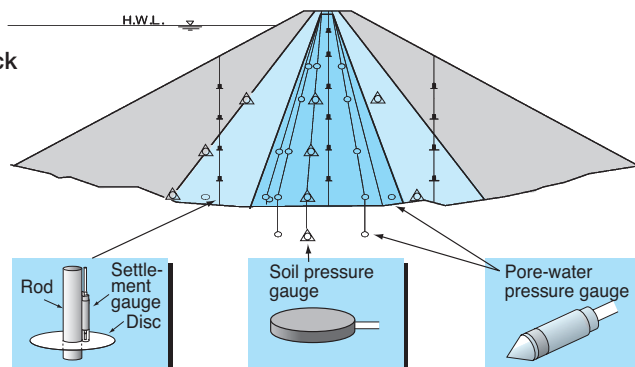
■ A list of Measuring Instruments

Measurement for surrounding ground and foundation bedrock

Items	Instruments	Type
Slope failure	Extensometer	KLG-A, NKLG-A
	In-place inclinometer	KB-AB, KB-AC, KB-JF, KB-KF NKB-LD, NKB-MD
	Water level meter	KW-C
Ground water level	Water level meter	KW-C
Infiltration flow	Pore-Water pressure gauge	KPA-PA, KPB-PA KPC-PA, KPD-PA

Measurement for embankment and foundation

Items	Instruments	Type
Displacement	Inclinometer	KB-JE, KB-KE
Subsidence of soil layer	Settlement transducer	KLA-A, NKLA-A, KLC-A
Displacement of bedrock	Rock displacement transducer	KLB-A
Displacement of rock surface	Inclinometer	KB-DB, KB-DE, KJB-A
		KB-AB/-AC/-DB/-EB, NKB-LD/-MD
Settlement	Settlement meter	Made to order
Pore-water pressure	Pore-water pressure gauge	KPA-/KPB-/KPC-/KPD-PA
Soil pressure	Soil pressure gauge	KDA-PA, KDC-PA, KDE-PA
Strain	Strain transducer	KM-B



Measurement for inspection gallery

Items	Instruments	Type
Stress of bar	Reinforcing bar meter	KSAT-A, KSA-A
Relative displacement between concretes	Joint meter	KJA-A
Concrete Stress	Concrete Stress meter	Made to order
Internal strain	Strain transducer Non-stress casing	KM-B, KM-BT KMF
Temperature	Thermocouple Temperature gauge	T KT-A

Concrete Dam Measurement

Embedment instruments for concrete dam are used for roughly three purposes: construction work management, work safety management and collection of research data.

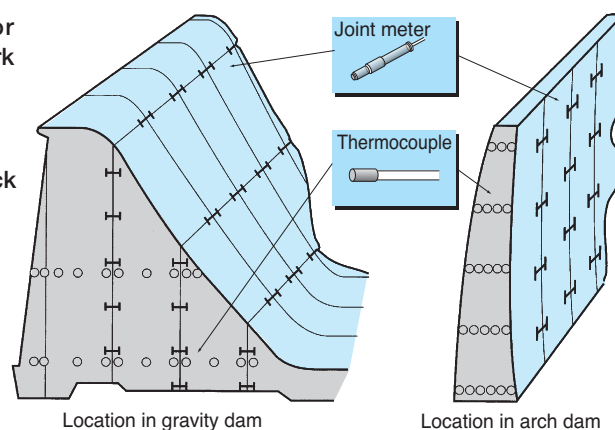
■ A list of Measuring Instruments

Measurement for surrounding ground and foundation bedrock

Items	Instruments	Type
Slope failure	Extensometer	KLG-A/-B, NKLG-A/-B
	In-place Inclino-meter	KB-AB, KB-AC KB-JF, KB-KF NKB-LD, NKB-MD
	Water level meter	KW-C
Underground water level	Water level meter	KW-C
Infiltration flow	Pore-water pressure gauge	KPA-PA, KPB-PA KPC-PA, KPD-PA

Measurement for embankment

Items	Instruments	Type
Leakage	Triangular-weir water meter	Made to order
Concrete stress	Stress meter	Other maker
	Strain transducer	KM-BT
	Non-stress casing	KM-BT, KMF
	Joint meter	KJB-A
Temperaute	Temperature gauge (Thermocouple)	KT-A T
Deformation	Plumb line	Other maker

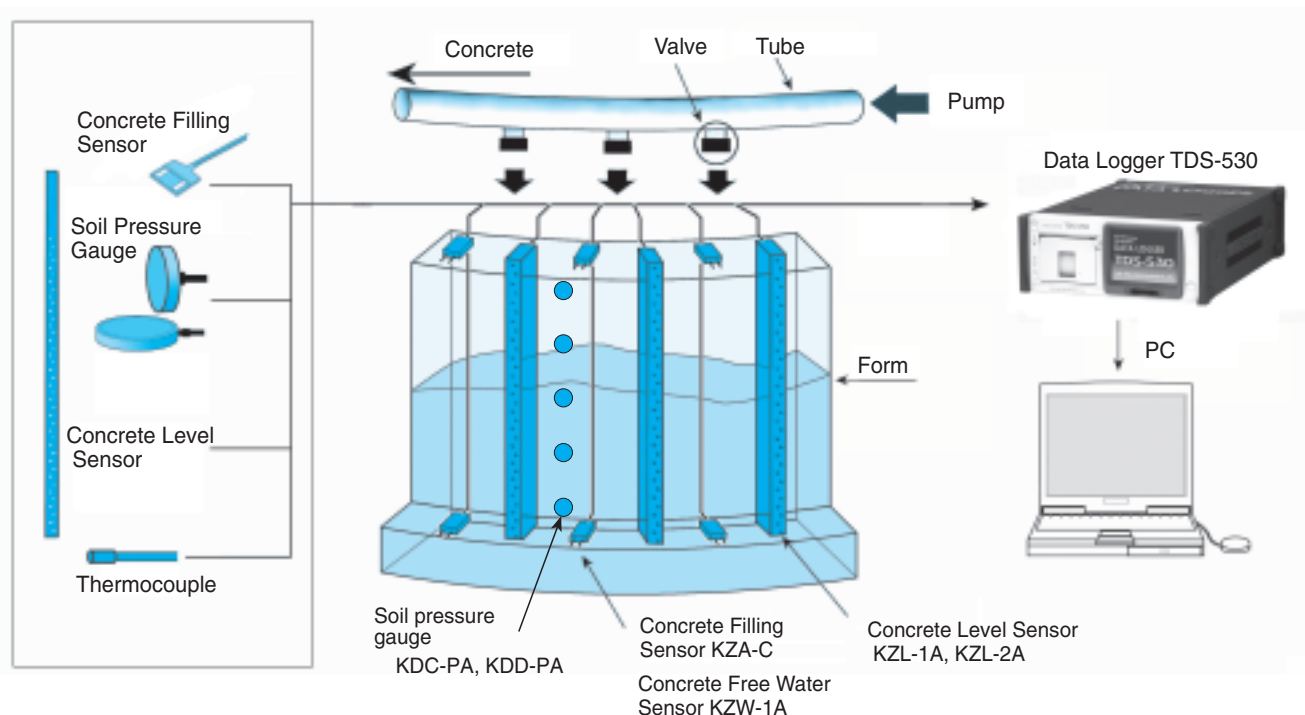


Measurement for foundation

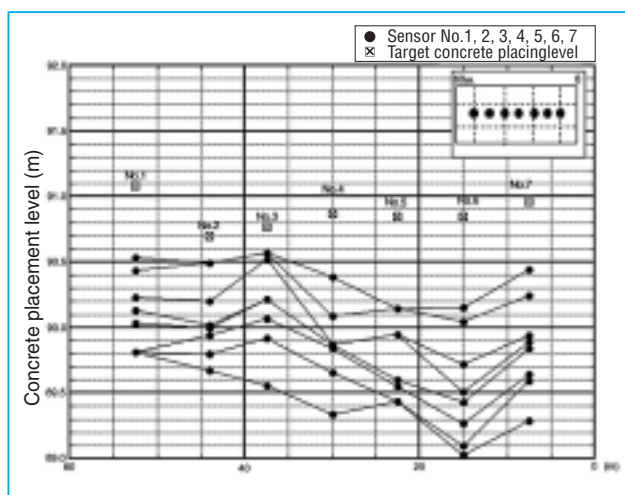
Items	Instruments	Type
Displacement of bedrock	Rock displacement transducer	KLB-A
Pore water pressure	Pore water pressure gauge	KPA-PA, KPB-PA KPC-PA, KPD-PA
Soil pressure	Soil pressure gauge	KDA-PA, KDC-PA KDE-PA
Uplift pressure	Uplift pressure transducer	PWF-S

11 Construction Management Measurement Based on The Status of Concrete

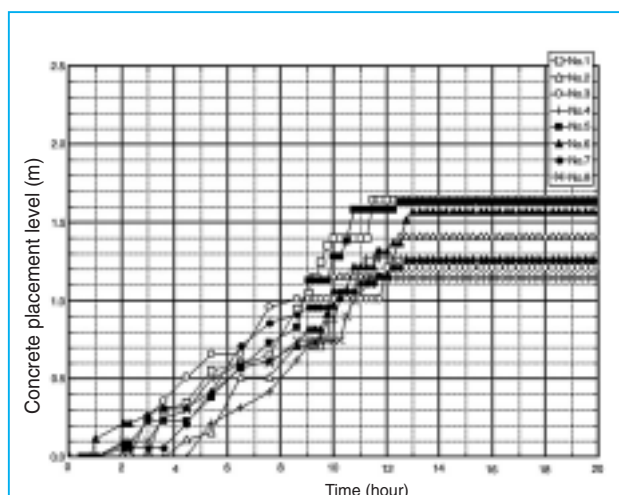
With the spread of an excellent self-filling and high fluid concrete, a method of concrete being placed in the form directly has been frequently used. When concrete is filled in a narrow space or complicated shaped form, it is very difficult to visually observe the filling status of concrete. Here, we suggest a concrete filling management system for observing the condition of concrete placement.



Distribution graph of concrete placement level



A graph of concrete level vs. time



A list of Measuring Instruments

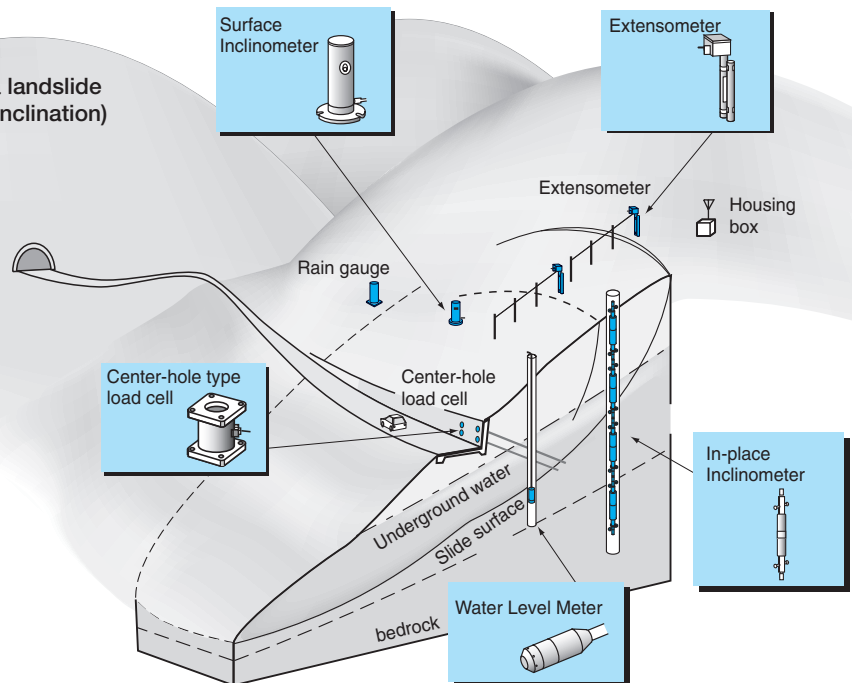
Measurement Items	Instruments	Type
Concrete placement level	Concrete level sensor	KZL-A
Concrete filling status	Concrete filling sensor	KZA-C
Side pressure of form	Soil pressure gauge	KDC-PA, KDD-PA
Pumping pressure	Flash diaphragm type pressure transducer	PWF-PA
Concrete temperature	Temperature gauge (thermocouple)	T, KT-A
	Concrete free water sensor	KZW-1A

12 Landslide Measurement

In making a landslide measurement plan, it is necessary to have a thorough knowledge of the three-dimensional profile and the ground-movement direction of landslide area. A measurement system that TML recommends is a centralized, automated measurement control system in which measuring instruments, data loggers, computers, and so on are connected in an online network. The addition of a communication function would turn this system into a wireless-communications measurement system.

Main measurement items

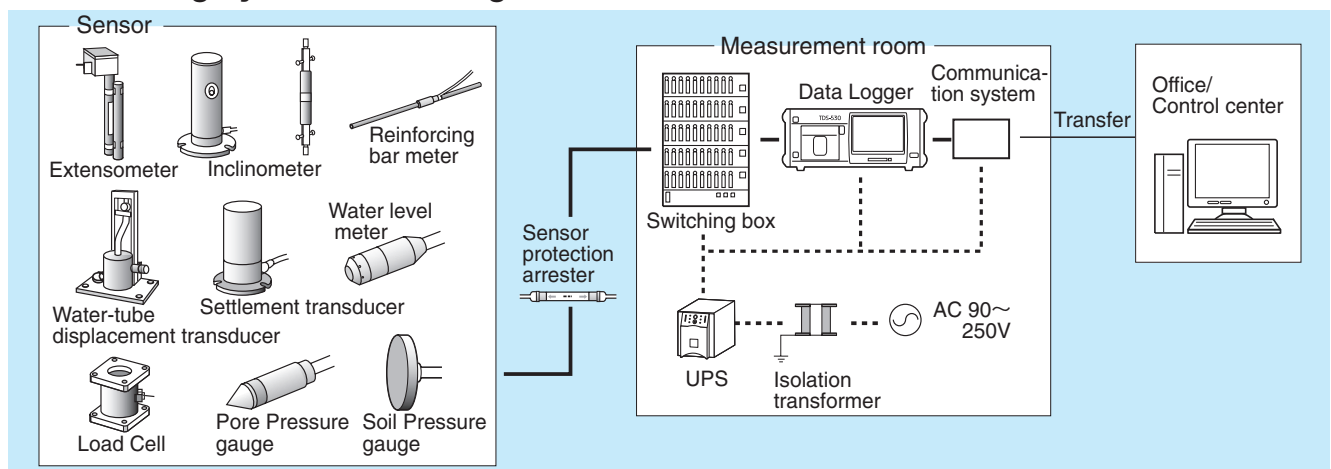
- Ground surface displacement caused by a landslide (conditions of expansion/contraction and inclination)
- Variation of underground water
- Sliding surface displacement
- External stress on and deformation of structures built to prevent landslide



A list of Measuring Instruments

Measurement objects	Measurement items	Instruments	Type
Variation of ground surface	Expansion	Extensometer	KLG-A, KLG-B, NKLG-A, NKLG-B
		Water-tube displacement meter	KWL-B/-E
	Inclination	Moving pile/survey apparatus	Other maker
Variation of Underground	Inclination	Inclinometer	KB-AB, KB-AC
		Insertion type inclinometer	KB-GC, KB-HC
	Soil mass movement	In-place inclinometer	KB-JE, KB-KE, NKB-LD, NKB-MD
Hydrological observation	Underground water pressure	Pipe strain meter	P401
	Wheather	Water level meter	KW-C
		Pore pressure gauge	KPB-PA, KPD-PA
Behaviour of strctures	Soil pressure	Rain gauge	Other maker
		Snow depth meter	Other maker
	Stress	Soil pressure gauge	KDB-PA, KDD-PA, KDF-PA
		Strain transducer	KM-A, KM-AT, KM-B, KM-BT
	Inclination	Re-bar meter	KSA-A, KSAT-A
		Insertion type inclinometer	KB-GC, KB-HC
		Small inclinometer	KB-DB, KB-EB, KB-AB, KB-AC
	Axial force of anchor	In-place inclinometer	KB-JE, KB-KE, NKB-LD, NKB-MD
		Center-hole load cell	CLC-NA, KCM-NA, KCE-NA

Measuring System Block Diagram

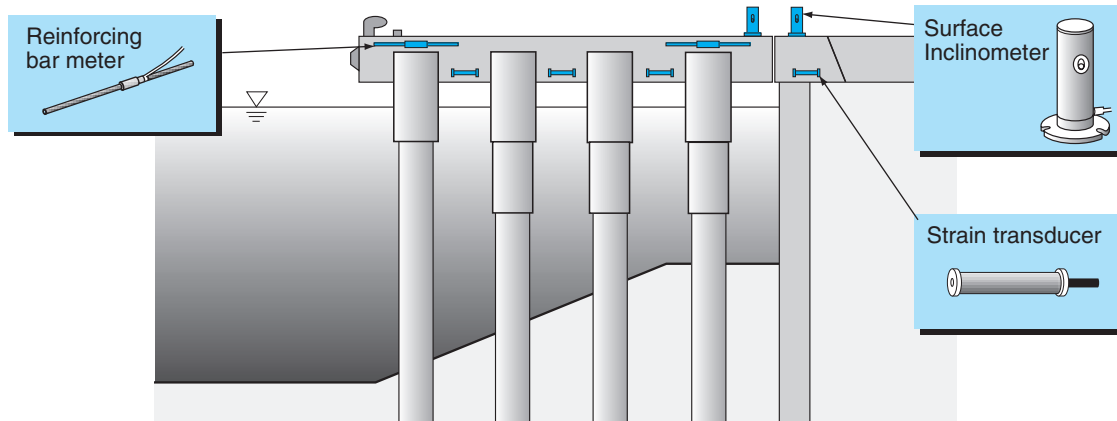


13 Marine Structure Measurement

Landing Pier Measurement

The following tests are conducted to survey the aging conditions of a pier:

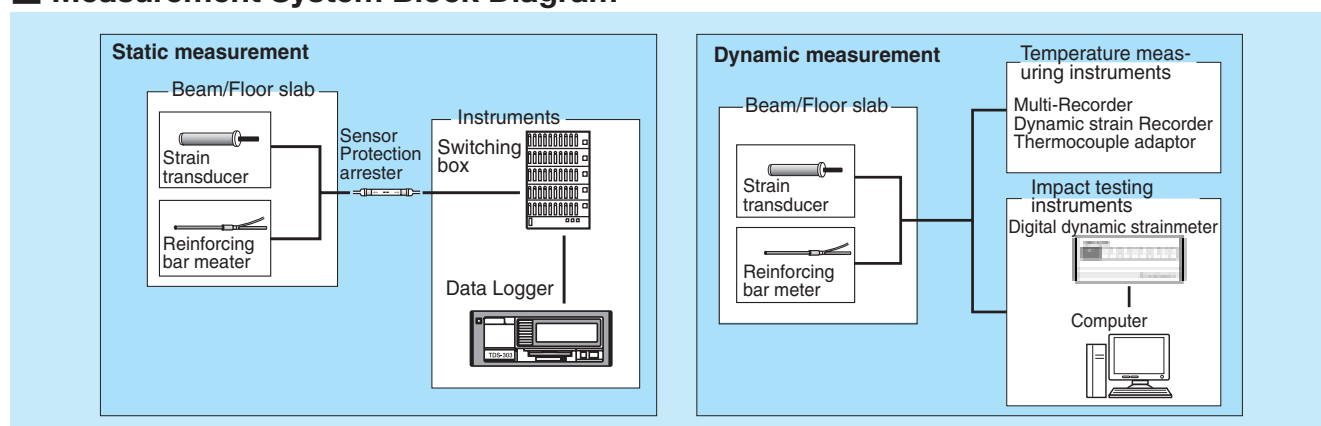
- **Static measurement**
Stress and strain on a pier under no-load conditions are measured.
- **Dynamic measurement**
Stress and strain on a pier are measured by running a vehicle, such as a forklift loaded with maximum weight assumed to be applied.
- The stress and strain of a pier are measured when a ship of 10,000 D.W.T. or heavier comes alongside the pier.



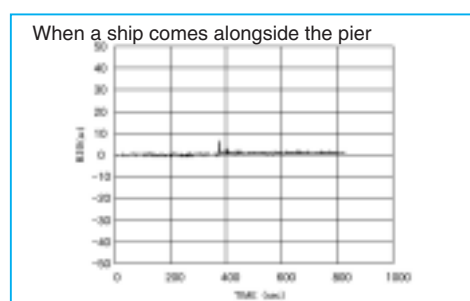
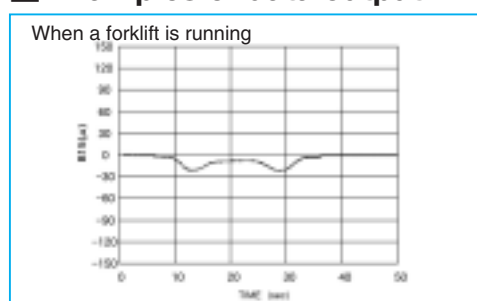
A list of Measuring Instruments

Items	Instruments	Type	Description
Stresses in piers	Reinforcing bar meter	KSA-A KSAT-A	Reinforcing bar stress transducers are installed in the directions perpendicular to and parallel to a normal line of a main beam reinforcement or a floor slab to measure strain on the bars.
Strains in piers	Strain transducer	KM-A/-AT KM-B/-BT	Strain transducers are installed in the directions perpendicular to and parallel to a normal line of a main beam reinforcement or a floor slab to measure strain on concrete.
Temperature in piers	Thermocouple Temperature gauge	T KT-A	Monitors temperature distribution within the pier
Inclination of pier	Inclinometer	KB-AB, KB-AC	Measures and monitors the behavior of pier

Measurement System Block Diagram

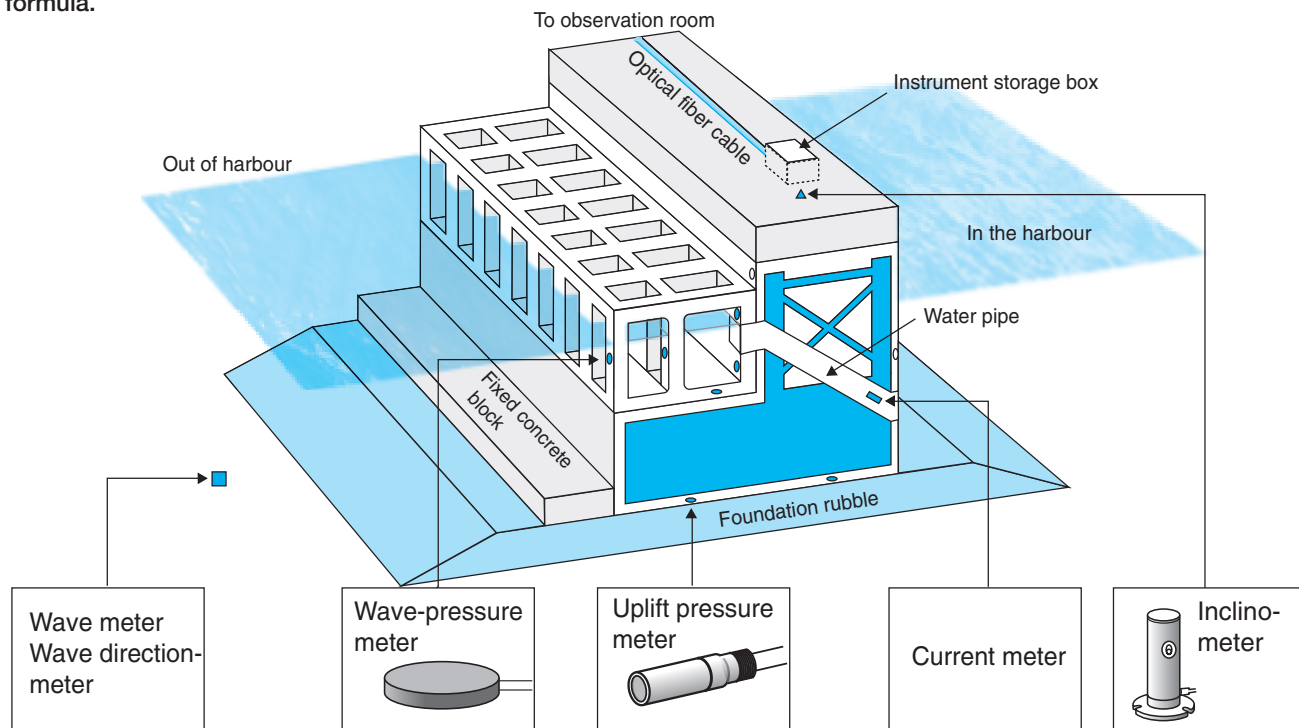


Examples of data output

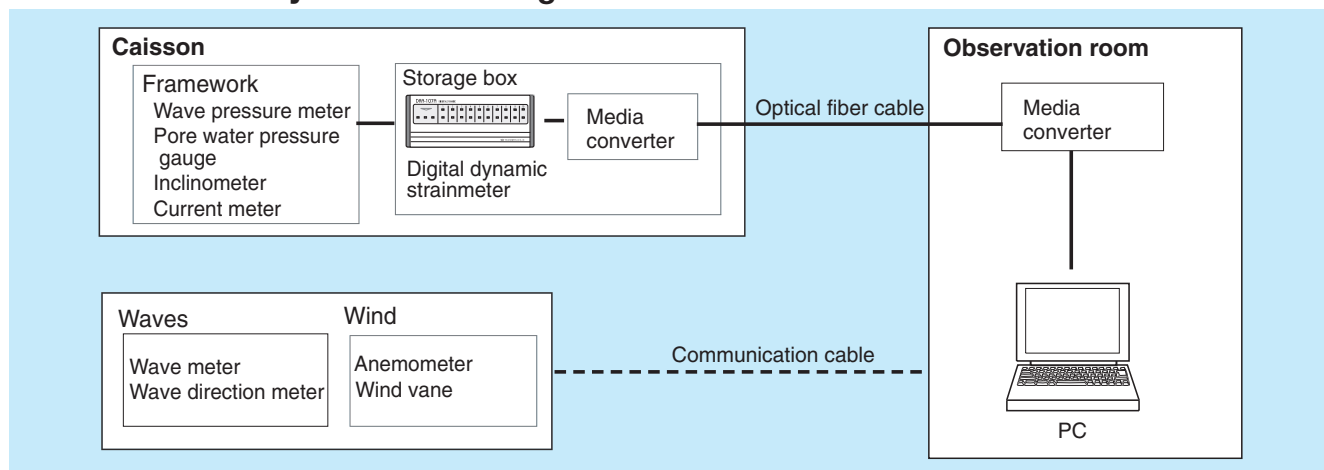


Caisson Type Quay Measurement

The details of distribution of wave pressure and uplift pressure acting on a caisson type quay in high waves are measured to verify the stability of wave endurance and confirm the practicability of using a designed wave pressure formula.



Measurement System Block Diagram

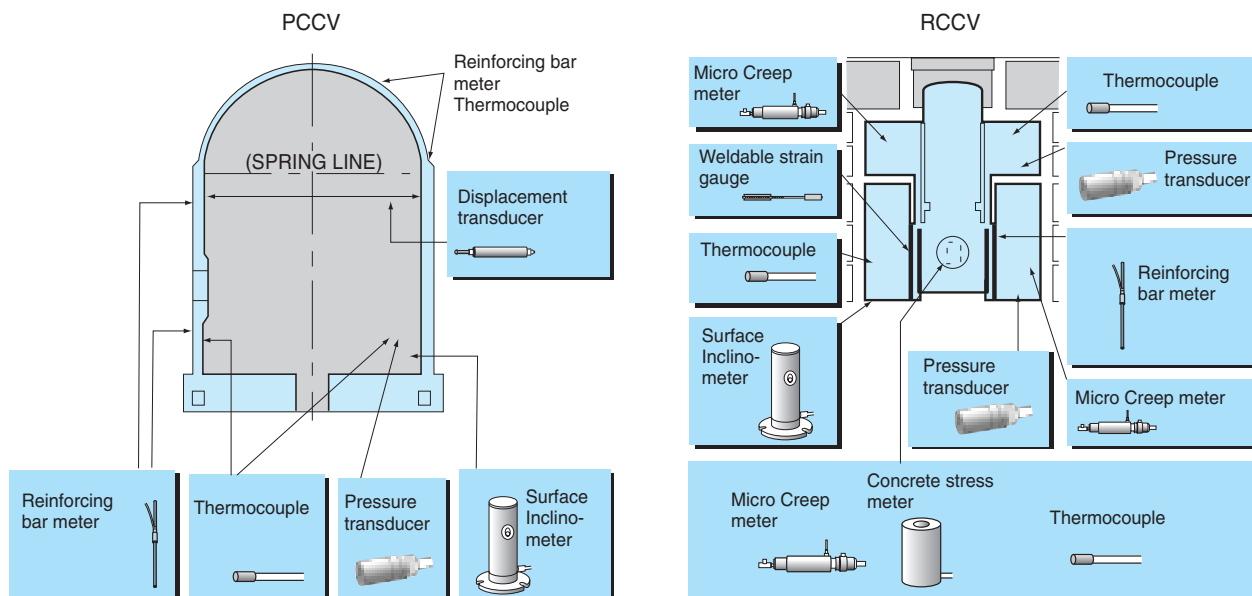


A list of Measuring Instruments

Measurement Items	Instruments	Type	Description
Wave pressure of members	Wave pressure meter	KDD-PA	Monitors wave pressure distribution of each member
Uplift pressure of bottom bed	Pore pressure gauge	KPA-PA	Measures uplift pressure acting on the bottom bed of the main body and the lower floor bed of retarding room
Inclination of caisson	Inclinometer	KB-AB, KB-AC	Monitors inclination of the main body.
Current speed in water pipe	Current meter	Other maker	Monitors the speed of current in the water pipe.
Waves	Wave meter	Other maker	Monitors time-dependent wave when receiving a pressure of wave.
	Wave direction meter	Other maker	
Wind	Anemometer	Other maker	Monitors time-dependent wind when receiving a pressure of wave.
	Wind vane	Other maker	

14 Nuclear Power Plant Measurement

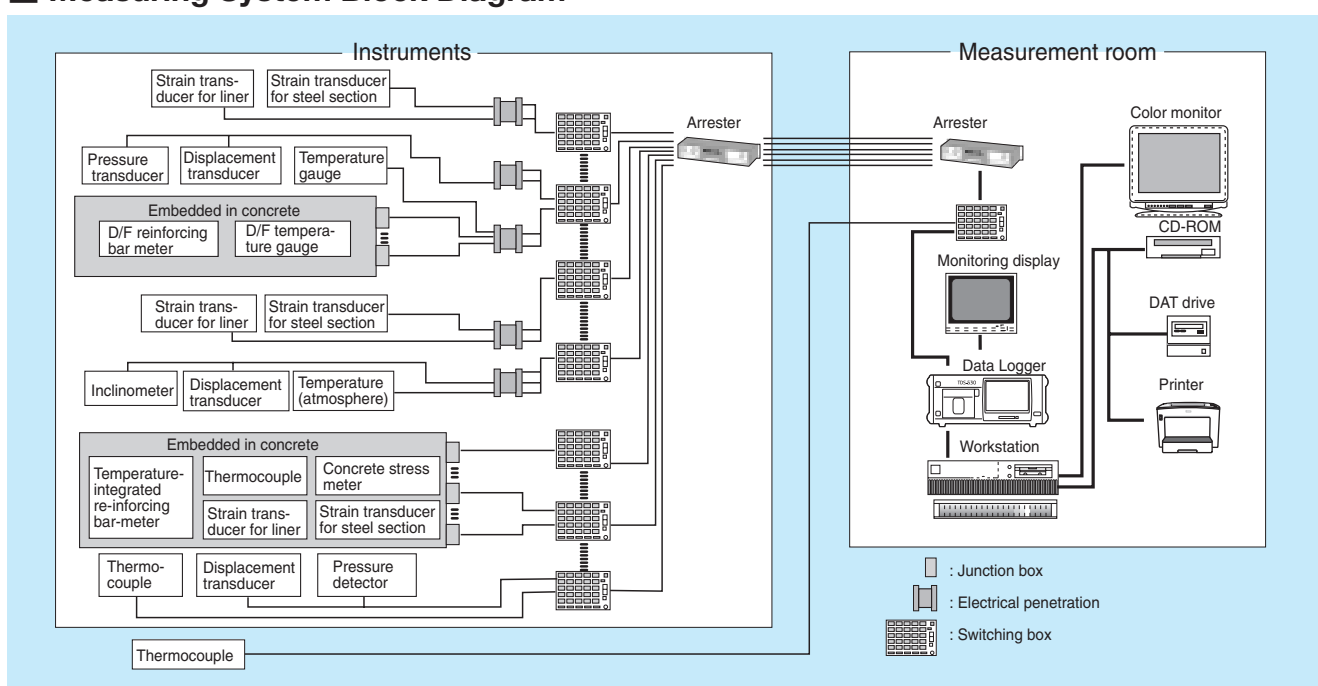
The structural integrity test (SIT) of a reactor containment vessel is carried out using various sensors.



A list of Measuring Instruments

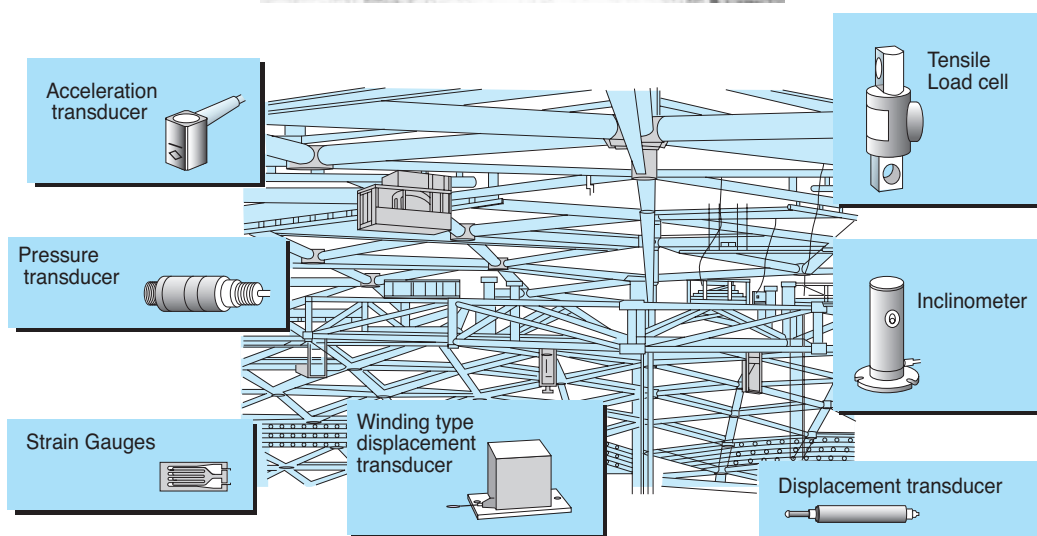
Measurement items	Instruments	Type
Behavior of the main body	Re-inforcing bar-meter	KSAT-A
Strain of liner section	Weldable strain gauge	AW, AWC-B
Deformation of containment vessel	Micro Creep Meter	KH-AS (Customized)
Deformation of access tunnel	Displacement Transducer	CDP-S (Customized)
Deformation of base mat	Concrete Stress Meter	CPS-A (Customized)
Temperature of the main body	Temperature Gauge	KT-A
	Thermocouple	T
Deformation of base mat	Inclinometer	KB-ABS (Customized)
Pressure on the main body	Pressure Transducer	KP-AS (Customized)

Measuring System Block Diagram



15 Large Roof and Dome Measurement

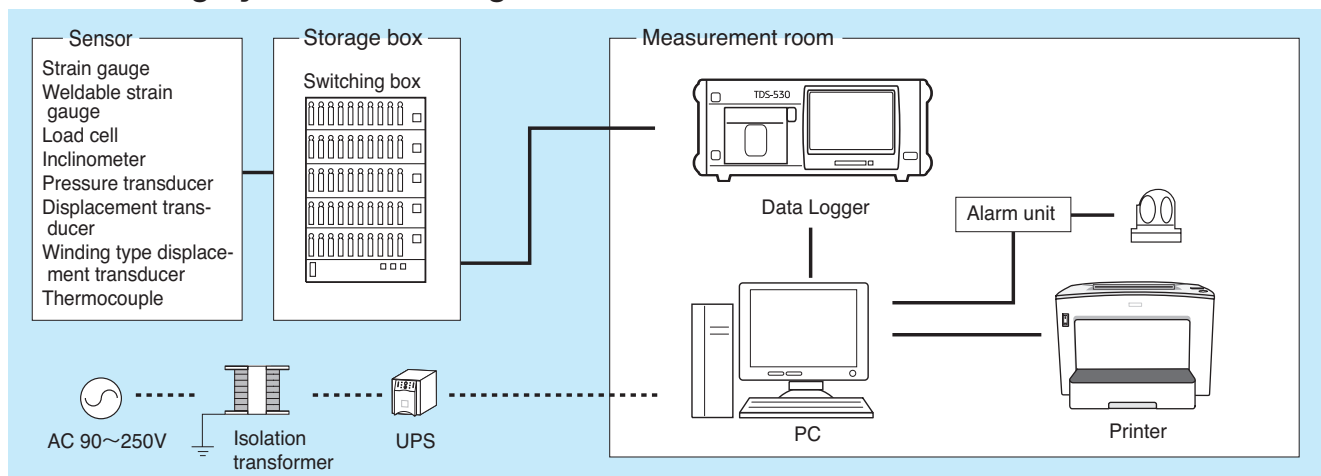
During construction of a dome and gymnasium, data on load and stress is collected using various sensors to verify the load bearing capacity (jacking-up and -down capacity).



A list of Measuring Instruments

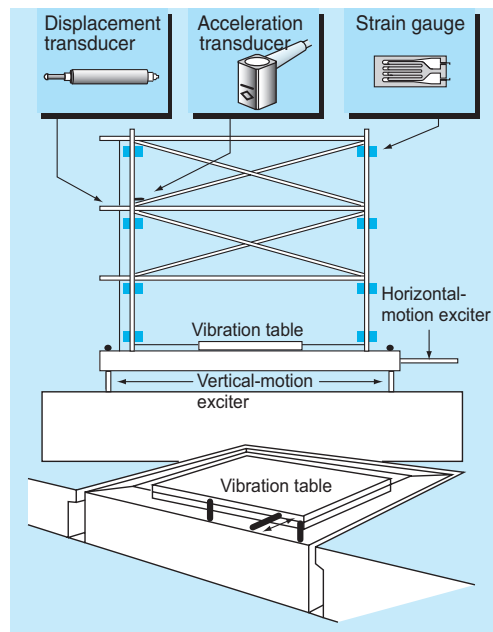
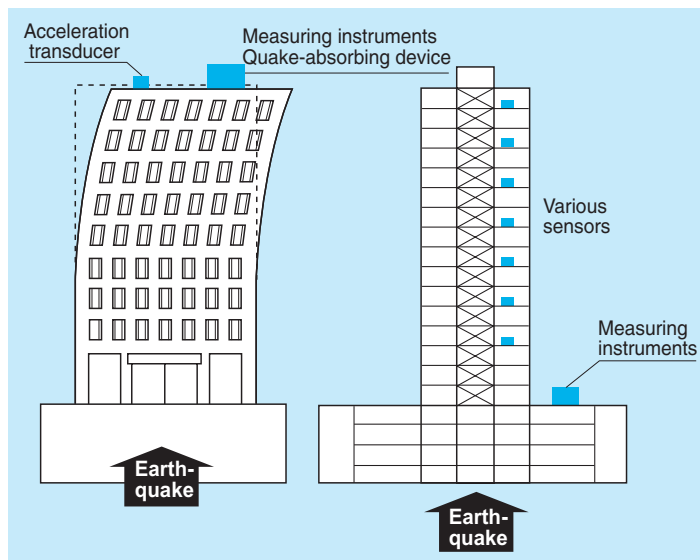
Measurement items	Instruments	Type	Description
Stresses in truss members and supports and tensile force of rods	Strain gauge	FLA, FCA, FRA	Bonded on supports and truss members to find stress from strain measurement.
	Weldable strain gauge	AW, AWC-B	Bonded on supports and truss members to find stress from strain measurement.
Lifting load	Load cell	TLP-NB	Installed at a lifting point within a dome to measure a tensile load.
Shearing deformation	Inclinometer	KB-AB, KB-AC	Installed at a key point within a dome to find a shearing deformation from measurement of inclination angle.
Jacking load	Pressure transducer	PWH-PA	Finds a jacking load by measuring a pressure using pressure transducer.
Vertical and horizontal displacement	Displacement transducer	CDP	Installed on truss, etc. to measure the amount of displacement.
		DP	Installed on truss, etc. to measure the amount of displacement.
Vibration of dome	Accelerometer	ARF-A	Installed on truss, etc. to measure acceleration in dynamic application.
Temperature outside/inside dome	Thermocouple, Temperature gauge	T KT-A	Measures temperature inside or outside the dome.

Measuring System Block Diagram



16 Quake Damping and Absorbing Measurement

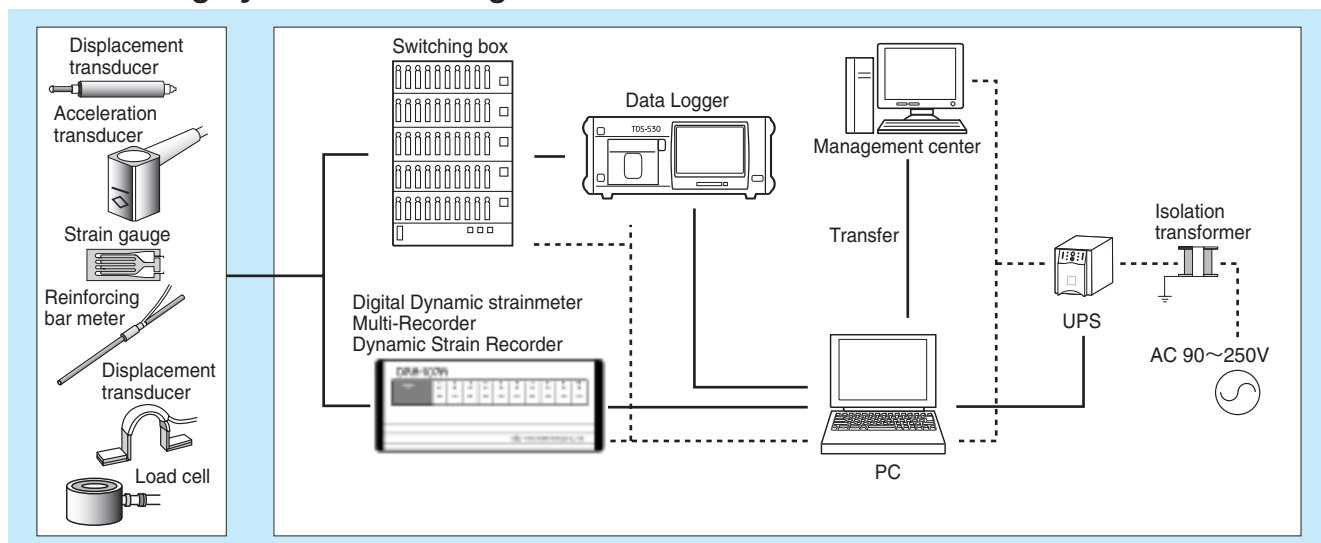
A quake-damping structure uses various types of damping materials. For example, laminated rubber having low horizontal rigidity, slide bearings and so on are designed as part of the quake-damping structure in order to damp seismic force. A quake-absorbing structure uses a powerful shock-absorbing device to absorb seismic energy. Static and dynamic conditions of a structure are measured to check its quake-damping and quake-absorbing performance..



A list of Measuring Instruments

Measurement items	Instruments	Type	Description
Vibration acceleration	Acceleration transducer	ARF-A	Installed on the foundation or beam of a structure to measure the vibration acceleration caused by earthquakes.
Vibration displacement	Displacement transducer	CDP	Measures the amount of vibration displacement caused by shaking of a structure.
Strain/stress	Strain gauge	FLA	Measures the strain and stress of each part of a structure.
	Reinforcing bar meter	KSA-A, KSAT-A	
Crack displacement	Displacement transducer	PI	Measures the degree of opening of a crack caused by earthquakes.
	Crack displacement transducer	KG-A	
Damper load, displacement	Load Cell	TCLP-NB	Measures the variation of dynamic displacement and load of dampers caused by earthquakes.
	Displacement transducer	CDP	

Measuring System Block Diagram



MEASURING EQUIPMENT

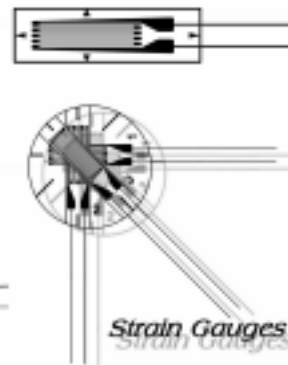


STRAIN GAUGES

Leadwire-integrated strain gauges



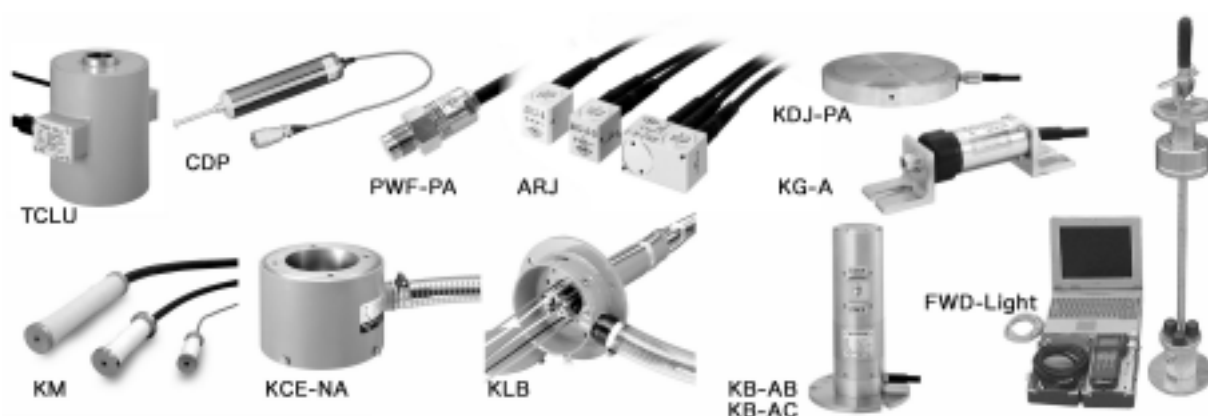
Weldable strain gauges



Strain Gauges

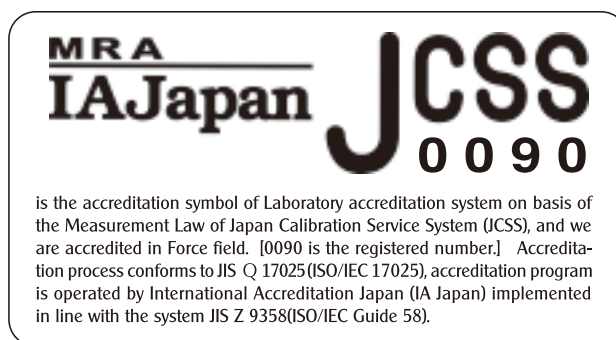


TRANSDUCERS



INSTRUMENTS





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