Korean Construction Standard

KCS 11 10 15 : 2019

Ground Measurement During Construction

December 06, 2019
http://www.kcsc.re.kr

국토교통부

Foreword

•To address needs caused by changes in the construction standard code system, the overlaps and conflicts between existing construction standards (design standard, standard specification) were compared and reviewed and then integrated into the newly enacted Construction Standard Code.

• Major matters related to the enactment and revision of this code are as follows:

Construction Standard	Main Content	Enacted or Revised (Year.Month)
KCS 11 10 15 : 2016	• The part corresponding to ground measurement during construction was enacted according to changes in the construction code system.	Enactment (June, 2016)

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1. Soft Ground Construction

1.1 General

1.1.1 Scope of Application

(1) The purpose of this code is to support safety management in soft ground construction.

(2) Measurement management for any purpose other than the one described in (1) above is described separately.

1.2 Materials

1.2.1 Types of Measurement Instrument

(1) Underground inclinometer: An underground inclinometer is used when ground displacement is expected due to soft ground or in the presence of an important structure within the range affected by the construction. The maximum measurement error of the measurement instrument should be within ± 1.0 mm.

(2) Water level meter: A water level meter is used when a change in the groundwater level is expected, and thus the groundwater level should be reflected in the measurement result analysis.

(3) Surface settlement gauge: Measurement error of the measurement instrument should be within ± 1.0 mm.

(4) Underground extensometer: An underground extensometer is used when an important underground structure is present at a position near to the site of soft ground excavation construction. Measurement error of the measurement instrument should be within ± 1.0 mm.

(5) The measurement range of pore water pressure should be determined by considering the pore water pressure on the design. Basically, the range of measurement should be over 1 MPa.

1.3 Construction

1.3.1 Installation of Measurement Instrument

(1) A measurement instrument should in principle be installed at a position determined by the design, but the installation position may be changed or a new installation position may be added in consultation with the construction supervisor by sufficiently considering the fact that a measurement instrument should be installed in advance to be utilized in construction management.

(2) Common standards for measurement instrument installation

① Casings should be installed for all the borings for measurement instrument installation, and the inner diameter of all borings should meet or exceed 86 mm.

② A boring should be adjustable within 1° in the X, Y, Z-axis directions so that it may be installed horizontally on the ground. The equipment should have sufficient performance to maintain the verticality during the boring work within 1°. In addition, the performance of the equipment should be approved by the construction supervisor in advance.

③ The position of installing a measurement instrument should be determined by obtaining the approval of the construction supervisor after performing measurement, before drilling and marking the measurement results and positions for the ground survey positions and the measurement instrument installation positions on the drawings. The drawings and the measurement result should be stored and maintained so that they may not be damaged.

④ Sand of which less than 5% passes through a 0.08 mm sieve may be used to fill the holes for installing a piezometer and a water level meter.

⑤ The pore size of the filter wrapping the piezometer tip should be less than 80 ㎛.

⑥ The diameter of the sand particles filled in the filter wrapping the piezometer tip should be greater than 75 ㎛.

⑦ The top 1 m part of the measurement instrument for which sand is put into a hole as a filling material should be filled with bentonite pellets to prevent the mixing of bentonite cement mix with the sand during grouting. The bentonite-cement mixing ratio should be determined to make the modulus of deformation equal to the strength of the surrounding ground by means of a test mixing in the presence of the construction supervisor, and the result of the test mixing should be submitted to the construction supervisor.

⑧ The grouting pressure of grouting equipment should be higher than 2.5 MPa. The performance of the equipment should be approved in advance by the construction supervisor.

⑨ The measurement instrument installation depth and the number of measurement instruments to be installed should be determined with reference to the soil survey-based geological columnar section and the boring result from the on-site survey and preliminary survey, and should be reported to the construction supervisor. The entry and installation of the measurement instruments should be managed based on the directions given by the construction supervisor. The changed number of measurement instruments should be settled accordingly.

⑩ Serial numbers should be given to individual measurement instruments according to the position, depth, and type, and labels should be attached to individual instruments for management.

(3) Surface Settlement Plate

① A surface settlement plate should be installed on the site after checking the consistency with the specifications and obtaining approval from the construction supervisor with regard to the consistency.

② A surface settlement plate should be installed before starting the filling work. A small amount of sand or high-quality soil should be placed on the original ground for leveling so that the settlement plate may be installed horizontally.

③ If there is contact between an external protective pipe and an internal settlement bar, the friction of the pipe may result in a measurement error. Therefore, a spacer should be installed to maintain the gap between an external protective pipe and an internal settlement bar. The pipes should be connected continuously by the same method until the filling reaches a predetermined height.

④ The settlement bar and the external protective pipe should be exposed appropriately over the filling soil after completing the filling work so that the measurement may not be hindered.

⑤ Immediately upon installing the settlement plate, the initial value before settlement should be measured by leveling. The measurement value may be used as an initial value after obtaining the approval from the construction supervisor.

⑥ To prevent the settlement plate from being transported or inclined during the filling work, the filling work should be performed manually with care in a diameter of 2 m and in a height of 1 m around the settlement plate, avoiding any measurement error.

⑦ A label with a serial number should be attached to each settlement plate to prevent any measurement error due to the confusion of the settlement serial number.

(4) Water Level Meter

① After placing a sand mat, a water level meter should be installed on the sand mat layer by attaching it to the protective pipe of a surface settlement plate with wire or cloth tape.

② A sand bag is fixed to the piezometer tip, and a casing is coupled.

③ The gauge is inserted until the tip reaches the PET mat. Sand is placed on the top of the tip at a thickness of over 50 cm. After completing the installation, a protective lid is placed on the top of the casing.

④ The entire connecting length of the casing should be recorded on the top of the installed casing for management.

⑤ For a water level meter installed outside the construction site, boring should be performed to a depth of 5.0 m at a position that is not affected by the underground stress and that does not disturb the traffic, and grouting with sand should be performed after installing the gauge.

(5) Underground inclinometer

① A measurement direction suitable for the purpose of stability management should be determined and approved by the construction supervisor.

② An installation hole with an internal diameter of 86 mm ~ 116 mm should be bored

down to the support layer through rotary wash boring.

③ The drilling depth should be checked using a tape measured with a ball weight.

④ Desliming should be performed with clean water after the drilling.

⑤ The end part of the initially inserted casing should be wrapped with an end cap so that no impurity is inserted into the casing.

⑥ Initially, the casings and couplings should be combined and arranged in the construction site office in advance according to the drilling depth, considering the horizontal deformation and the vertical deformation. In addition, after riveting some casings and couplings and sealing them with rubber tape, a serial number should be given to each combination and written on the casing. After receiving inspection by the construction supervisor, the casings should be carried into the construction sites and inserted into the casing grooves inside the installation holes according to the serial numbers. While riveting and sealing the connecting parts, the casings should be installed down to the support layer (bedrock).

⑦ Backfilling materials should be selected according to the soil type around the measurement pipe.

A. Clay: cement bentonite solution

B. Gravel: sand

C. Weathered rock: cement grouting

⑧ A cap should be placed on the top, and measurement instrument protection fences should be installed to prevent damage.

⑨ After the grouting material is cured, the settled area should be filled again with the grouting material.

⑩ After completing the backfill curing, the area around the measurement hole should be excavated to an area of 0.4 m × 0.4 m on the top and 1.0 m × 1.0 m on the bottom, and to a depth of 0.3 m. After placing protective concrete, a protection box is inserted into the concrete to a depth of 20 cm, and the concrete is cured to install the PAD for measurement and the protection box.

⑪ The initial value is measured.

(6) Pore Water Pressure Gauge

① Boreholes having an internal diameter of 86 mm ~ 116 mm should be bored down to a predetermined depth through rotary wash boring, while installing the casing. A crawler drill should not be used.

② After removing a counterfort retaining wall casing around the position where a piezometer tip is to be installed, the slime should be washed off with clean water. The cleaning should not be performed with air.

③ The bottom of the piezometer tip should be filled with sand to a height greater than 20

cm.

④ The drilling depth should be checked using a tape measure with a ball weight.

⑤ The tip of the pore water pressure gauge should be saturated with water for 24 hours to remove the bubbles in the tip, and the initial value should be read using the method described in the catalogue of the measurement instrument and recorded.

⑥ The saturated pore water pressure gauge should be put into the test hole to verify the normal operation of the measurement instrument and the predetermined precision to obtain the approval of the construction supervisor. The pore water pressure gauge should be transported to the construction site, with the tip immersed in water. Then, the pore water pressure gauge should be put into a saturated package or filter bag to install it at a specific depth.

⑦ Sand should be filled at the top of the piezometer to a height over 20 cm and compacted to form a permeable layer.

⑧ After removing the casing to a length of about 1 m, to prevent the infiltration of the bentonite grouting solution into the sand layer, a bentonite plug is formed by placing bentonite pellets having a thickness of 100 cm on the top of the sand layer and compacting the pellets.

⑨ While removing the casing, cement bentonite grouting is performed using a grouting hose to form an impermeable layer up to the ground surface (sand mat layer). The bentonite-cement mixing ratio should be determined to make the modulus of deformation equal to the strength of the surrounding ground by means of a test mixing. After the grouting material is cured, the settled area should be filled with the grouting material again.

⑩ While grouting is performed, in preparation for excessive horizontal displacement, snaking is performed with the underground and surface cables to prevent the disconnection of the cable by ground deformation. In addition, a protective pipe should be inserted over 1 m into the hole to prevent cable disconnection.

⑪ The initial value should be measured at least 72 hours after inputting bentonite pellets following the completion of the grouting solution curing.

⑫ For the protection of the cable from the filling work, snaking of the cable should be performed on the surface, and the cable should be inserted into the protective pipe to avoid damage to the cable by the filling work.

(7) Differential Settlement Gauge

① An installation hole with an internal diameter of 86 mm ~ 116 mm should be bored down to the support layer, while installing a casing for the hole.

② Desliming should be performed after the drilling, with clean water.

③ The drilling depth should be checked using a tape measure with a ball weight.

④ The end part of the initially inserted casing should be wrapped with an end cap so that no impurity is inserted into the casing.

⑤ Initially, the casings and couplings should be combined and arranged in the construction site office in advance according to the drilling depth, considering the horizontal deformation and the vertical deformation. In addition, after riveting some casings and couplings and sealing them with rubber tape, a serial number should be given to each combination and written on the casing. A magnetic sensor should be attached at the installation depth, and inspected by the construction supervisor. Then, the casings should be carried into the construction sites and inserted into the casing grooves inside the installation holes according to the serial numbers, using the grouting hose. While riveting and sealing the connecting parts, the casings should be installed down to the support layer.

⑥ Datum magnets should be attached to the bottom end and spider magnets should be attached to each measurement point. The magnets should be connected to the upper part with a flexible cord. A plate magnet is attached on the ground surface. However, considering the settlement that may occur on each layer, a spider magnet should be installed just below a telescopic coupling.

⑦ The casing should be removed to the differential settlement gauge installation point, and the cord connected to the spider magnets is removed to be settled in the borehole.

⑧ The same as ⑨ under (6) Pore Water Pressure Gauge.

⑨ The works described in ⑦ and ⑧ are repeated to install the magnets at each point and to perform grouting. After that, the hose is removed.

⑩ The initial value is measured.

1.3.2 Correction of Measurement Instrument

(1) The normal operation of a measurement instrument should be tested before and immediately after the installation. If necessary, the measurement instrument should be calibrated.

(2) If the measurement value is changed unusually during the measurement, the normal operation of the measurement instrument should be checked. If necessary, the measurement instrument should be calibrated.

1.3.3 Protection of Measurement Instrument

(1) Protective fences should be installed, and a signboard should be installed at a clearly viewable position to prevent damage to or poor operation of the measurement instruments due to settlement or filling works following the installation of the measurement instruments.

(2) Protective fences should be arranged in a rectangular shape with a measurement instrument at the center. Each protective fence should be firmly fixed with thick wires.

(3) The person in charge of the maintenance of the measurement instruments and protective fences should be an engineer in charge of the task. A label showing the affiliation, name, and contact number of the person in charge of the maintenance should be attached to the fences for management.

(4) If damage is caused to a measurement instrument by external factors, the damage should be immediately reported to the superintendent, and the measurement instrument should be installed again.

(5) If loss of a measurement instrument is caused by the construction works and careless management, the measurement instruments should be installed again and the expense should be paid by the contractor.

1.3.4 Installation of Data Transmission Cable

(1) A cable for the transmission of measurement data that has an appropriate format for continuous measurement should be selected. An installation plan should be prepared with regard to the cable routing, communication protocol, cable connection and access.

(2) The measurement instrument cable should be a cable that is exclusively for the measurement instrument. A single cable with no connection point from the laying point to the measurement room should be used.

(3) The cable should be laid with sufficient slack to avoid being subjected to tension due to the settlement of the measurement instrument.

(4) The cables of all measurement instruments should be protected by installing a pipe for measurement.

(5) The cross-sectional area of the cable should not exceed 32% of the cross-sectional area of the pipe for measurement.

(6) A pipe for measurement should be used only for a single measurement cable. However, another cable that will not cause a communication disruption for the measurement cable may be used together with the measurement cable, with the approval of the superintendent.

(7) The ends of the cable should be water-proofed to prevent the infiltration of water during measurement or maintenance.

(8) Information about the type of measurement instrument, serial number, and cable type should be marked at the ends of the cable so that the cables may not be confused.

(9) Considering the potential need for future expansion and extension, all equipment for data transmission should be compatible in preparation for further measurement system operation.

1.3.5 Inspection and Testing According to Measurement System Installation

(1) The inspection performed at the entry of the measurement instruments to the construction site should be performed on all the measurement instruments with the attached test result reports

from authorized institutions. However, these may be replaced by test result reports from the manufacturers at the discretion of the ordering body.

(2) After the entry to the construction site, the measurement instruments should be examined and the initial values measured through experiments with the equipment before utilization.

1.3.6 Management of Measurement Instruments

(1) The analytical equipment and systems should be installed in the office at the construction site so that the measurement results may be analyzed on site.

(2) The measurement instruments should be managed through the methods and procedures provided by the manufacturers to preserve the performance and secure the reliability of the measurement results.

(3) To prevent failures or malfunctions, the measurement instruments should be installed according to the specifications. A faulty measurement instrument should be immediately replaced at the expense of the contractor.

(4) Protective fences around the measurement instruments should be installed and maintained to protect them from vehicles and equipment, and the construction site workers should be informed about the measurement instruments. Filling work around a measurement instrument should be performed manually under the supervision of an engineer in charge of the measurement instrument. If a measurement instrument is damaged due to carelessness, the instrument should be immediately recovered at the expense of the contractor.

1.3.7 Performance of Measurement

(1) Generals related to Performance of Measurement

① Measurement instruments that are selected and purchased should be appropriate for the conditions of the construction site and the purposes of utilization. The specifications of various instruments should be submitted to and approved by the superintendent before their purchase and installation.

② Measurement management works, including the selection, purchasing, and installation of measurement instruments as well as the performance of measurement, should be carried out by exclusive measurement agents or measurement management experts with equivalent capabilities.

③ The initial values of all measurement instruments should be measured in the presence of the superintendent. The results should be immediately summarized and submitted to the superintendent, who should confirm the results.

④ Leveling should in principle be performed by using a leveling meter. If site conditions do not allow, leveling may be performed through indirect measurement by using a light wave rangefinder. In addition, a measurement instrument used for task performance

should have higher than required performance or better. The instrument's performance should be approved in advance by the superintendent.

⑤ Leveling should be performed each time the initial value is measured for all installed measurement instruments (settlement plate, differential settlement gauge at different depths, etc.). All the measurement values should be marked with EL (elevation) for management.

⑥ The contractor should maintain a record of all measurement data. The measurement values should be submitted to the superintendent, and only approved measurement values may be recognized as the measurement result for which payment is made.

(2) Surface Settlement Plate

① Immediately after a task is initiated, solid and unmovable temporary bench marks (TBM) should be made at a maximum interval of 500 m on the fixed ground outside the construction site, referring to the measurement arrangement drawing. From the first class bench marks located inside the task site, round-trip leveling should be performed according to the first class leveling standard to calculate the EL of the TBM to use as a reference point for leveling.

② A settlement plate management zone to which the TBM is applied is determined, with reference to the established TBM.

③ Leveling is performed by measuring the height difference between the TBM and the top of the rod connected to the settlement plate.

④ Settlement is defined as the different between the initial EL and the measured EL.

⑤ Each time, leveling with the settlement plate should be performed in the unit of the management zone. The measurement result should be integrated with the TBM to test the precision of the measurement and to correct the error. The measurement activity should be summarized in the measurement field book and the settlement management logbook to be confirmed.

⑥ After completing each measurement, the settlement value should be written on the time-settlement plot to verify the abnormality of measurement. If an anomaly is found, measurement should be performed again immediately to avoid incorrect measurement.

⑦ Each time leveling is performed with the settlement plate, measurement should be performed at the top of the filling work to be used in the analysis and inverse analysis of the measurement data.

(3) Water Level meter

① The initial groundwater level in the original ground before the load filling should be the groundwater level measured in the boring survey hole during the confirmation boring survey or the laying work.

② The initial value and the measurement value should be submitted to and confirmed by

the superintendent.

③ The measurement value should be taken using the level of the settlement bar of the surface settlement plate and the casing length of the water level meter, and should be calculated as EL.

④ Leveling should be performed on a regular basis for the top of the casing of a water level meter installed outside the task zone to verify the settlement of the casing.

(4) Underground inclinometer

① The measurement direction should be marked on the label to keep it constant. Measurement should be performed from the bottom of the casing to the upper part, at intervals of 0.5 m.

② The initial value and the measurement value should be submitted to and confirmed by the superintendent.

(5) Pore Water Pressure Gauge

① Measurement should not be performed if filling work is being carried out or if heavy equipment is present within a radius twice as large as the depth of the soft ground layer in the area where the pore water pressure gauge is installed.

② The initial value and the measurement value should be submitted to and confirmed by the superintendent.

③ The measurement values should be corrected to reflect the variation in the groundwater level.

④ The temperature should be measured at each measurement instrument.

⑤ Correction should be automatically performed by the analytical software.

⑥ The variation of the installation depth of the pore water pressure gauge due to settlement should be calculated on the basis of the measurement results obtained from the differential settlement gauge to correct the measurement values.

(6) Differential Settlement Gauge

① Measurement should be performed by measuring the relative displacements from the datum magnetics to the spider magnetics and plate magnetics, in that order.

② The measurement unit should be mm.

③ The initial value and the measurement value should be submitted to and confirmed by the superintendent.

1.3.8 Measurement Frequency

(1) Measurement should be performed at the measurement frequency described in Table 1.3-1 according to the measurement frequency and period. The measurement result should be immediately reported according to the predetermined schedule.

(2) The measurement frequency should conform to the design drawings and the specifications, but may be increased or decreased depending on construction site conditions and circumstances.

(3) The measurement items and frequency may be adjusted according to construction site conditions and ground conditions, with the approval of the superintendent.

Table 1.3-1 Soft Ground Measurement Frequency

Measurement Instrument	From completion of filling work to 1 month	1 ~ 3 months	After 3 months	Remark
Underground inclinometer	Once per day	Once per week	Once every two weeks	Manual measurement
Water level meter	Once per day	Once per week	Once every two weeks	Manual measurement
Surface settlement plate	Once per day	Once per week	Once every two weeks	Manual measurement
Differential settlement gauge	Once per day	Once per week	Once every two weeks	Manual measurement
Pore water pressure gauge	Once per day	Once per week	Once every two weeks	Manual measurement

Note 1) The measurement frequency described above may be adjusted according to the equilateral increment or decrement in the occurrence of risks or displacement convergence, the amount of displacement, or other site conditions.

1.3.9 Measurement Period

The time for finishing measurement management should be determined by an advanced engineer in the field of soil work in consultation with the superintendent, based on the analysis of the measurement values.

1.3.10 Summary and Analysis of Measurement Result

(1) The analysis of the measurement result should be performed by a specialized engineer who is graded as an advanced engineer or higher.

(2) The measurement result should be analyzed by an advanced engineer with extensive experience in soil work, and the result of the analysis should be submitted to the superintendent. Every effort possible should be made to prevent any problems in terms of the constructability and the verification of the number of construction works.

(3) Various measurement works should be performed systematically during the construction works, and the results of such measurements should be reflected in the design and construction. The design should be changed to be more suitable to the construction site in order to improve the safety and economic feasibility of the construction work, as well as the constructability.

(4) The measurement results should be arranged and preserved so that they may be used for routine construction management, and reflected in future plans.

(5) On the basis of the ground survey result and the measurement data, the time coefficient, consolidation coefficient, compression index, and ground strength should be calculated for each management area unit and each completion stage. The period, amount, and rate of filling work as well as the settlement period should be compared with the ground design plan and re-analyzed to prepare countermeasures by changing the filling work plan and the leaving period, providing feedback to the construction work.

(6) The measurement result obtained from the underground inclinometer should be marked for analysis on the plot showing the slope variation depending on the measurement depth together with the management reference values depending on the filling height at the measurement time point.

(7) Following ground treatment and load filling work, the presence of the predicted consolidation facilitation effect should be verified. If the measurement taken is not in accordance with the prediction, the causes should be investigated and analyzed in order to prepare appropriate countermeasures.

(8) In an area where the depth of soft ground is rapidly changing, the nonuniform settlement resulting from the difference in the residual settlement should be calculated to analyze the effect on the facilities and the underground utilities for management.

1.3.11 Measurement Management Standard

(1) At a stability management position, the deformation, deformation rate, settlement, and settlement rate of the foundation ground should be measured and analyzed daily in detail during the filling work and until 7 days after the completion of the filling work so that construction may be carried out in a stable state.

(2) As representative ground constants representing the complex layer composition state are applied to the design of soft ground, the design settlement values are often inconsistent with the actually measured settlement values. Therefore, regardless of the consolidation theory, an equation that is appropriate for the actual settlement curve should be derived to predict future settlement. If the prediction based on the actual measurement values is not in accordance with the existing design, the actual measurement values should be reflected in the construction works and design again.

1.3.12 Report of Measurement Result

(1) The person in charge of measurement should report the measurement result on a daily basis immediately after performing the measurement.

(2) The person in charge of measurement should summarize the deformation, increment and decrement, rate of increment and decrement, and positions included in the measurement data, and report the result on a weekly basis.

(3) The person in charge of measurement should summarize in plots the deformation, increment and decrement, rate of increment and decrement, and positions included in the measurement data, analyze this in comparison with the management standards, and report the result on a monthly basis.

(4) In cases where a significantly large displacement occurs or where an emergency measure is necessary due to the site conditions, the result of the measurement should be reported immediately to enable appropriate actions to be taken.

(5) After the measurement for a target facility is completed, all the measurement records and accomplishment analysis data during the construction period should be summarized and reported to the superintendent.

2. Slope Face Cutting Construction

2.1 General

2.1.1 Scope of Application

(1) The purpose of measurement management in this code is to ensure safety management during slope surface cutting construction.

(2) The measurement for the back face structure protection during the slope face cutting should conform to the measurement specifications during excavation construction.

(3) Measurement management for any purpose other than the one described in (1) and (2) above will be described separately.

2.2 Materials

2.2.1 Measurement Instruments

(1) Measurement of surface displacement, inclination, and crack (extensometer; GPS): Extensometers and GPS are installed to measure the surface displacement of a slope surface. The default level of precision should be 1 mm.

(2) Underground inclinometer: An underground inclinometer is installed to measure the underground displacement caused by activities on the slope's surface. A boring survey should be performed in advance to obtain the physical property data of the ground for boring. The measurement instrument should generally be installed in the borehole. The default level of precision should be 1 mm.

(3) Water level meter: A water level meter is installed to measure the variation of the natural water level on the slope surface. The default level of precision should be 1 cm. A filter having a

permeability coefficient twice as large as that of the slope surface should be included in the water level meter.

(4) Pore water pressure gauge: A pore water pressure gauge is installed to measure the variation of the pore water pressure depending on the rainfall on the slope surface and the groundwater level variation. The gauge should be able to measure the variation in the pore water pressure at a level of precision higher than 0.1 MPa.

(5) Rainfall meter: A rainfall meter is installed on the ground surface of the slope surface to obtain meteorological data about the rainfall on the slope surface. The rainfall meter should have the capability to measure the rainfall at a precision of 1 mm or higher. The snowfall in winter should be converted to rainfall, and the instrument should be able to be operated in cold weather.

2.2.2 Measurement Data Acquisition System

(1) A measurement data acquisition system should be selected after considering the characteristics of slope surface collapse and sliding progress, the importance of the slope surface and the facilities on the slope surface, the effect of damage occurrence, economic feasibility, and measurement frequency.

(2) To prevent or minimize the damage that may be caused by the collapse or sliding of slope surfaces, detecting the signs early is important, and monitoring the information and transferring and treating the information rapidly are necessary. It is appropriate to use an automated technology that may collect, process, and interpret the measurement data in a single system.

2.3 Construction

2.3.1 Installation of Measurement Instrument

(1) The measurement instruments that are installed in the underground surface should be installed using a drilling device that may minimize the disturbance of the ground.

(2) The bench mark of a measurement instrument installed by drilling should be installed by drilling down to the rock at a point under the expected sliding surface where almost no displacement occurs. For the measurement of slope surface displacement, the bench mark should be made at a position that is not affected by the deformation of the slope's surface.

(3) The installation should be performed before the start of the construction work at the positions where displacement is predicted by the preliminary survey. Measurement instruments that are difficult to install before the completion of the slope surface construction works should be installed within 48 to 72 hours following the completion of the slope surface construction works.

2.3.2 Correction of Measurement Instrument

(1) The normal operation of a measurement instrument should be tested before and immediately after installation. If necessary, the measurement instrument should be calibrated.

(2) If the measurement value is changed unusually during the measurement, the normal operation of the measurement instrument should be checked. If necessary, the measurement instrument should be calibrated.

2.3.3 Protection of Measurement Instrument

(1) The area around an installed measurement instrument should be sufficiently protected from the adverse effects of the weather and the growth of animals and plants for the management of the measurement instrument and the performance of the measurement.

(2) Since a rainfall gauge should be able to accurately measure the rainfall at the position where the gauge is installed, it should be installed at a position that is not affected by falling leaves or other factors.

2.3.4 Installation of Data Transmission Cable

(1) Since the collapse of a slope surface requires real-time measurement, a cable with an appropriate format for continuous transmission of measurement data should be selected.

(2) The measurement instrument cable should be a cable exclusively for the measurement instrument. A single cable with no connection points from the laying point to the measurement room should be used.

(3) The cables of all measurement instruments should be protected by installing a pipe for measurement.

(4) The ends of the cable should be water-proofed to prevent the infiltration of water from measurement to maintenance.

2.3.5 Inspection and Testing According to Measurement System Installation

Must conform to 1.3.5.

2.3.6 Management of Measurement Instrument

(1) The area around an installed measurement instrument should be sufficiently protected from the adverse effects of weather, the growth of plant life and animal habitats for the management of the measurement instrument and the performance of measurement. A signboard on which the title of measurement, position of measurement, initial measurement date, and initial measurement values are written should be installed for management.

(2) In cases where a measurement instrument has been damaged by the weather, the growth of plant life and animal habitats, blasting or other causes, another measurement instrument should be installed at an adjacent position to continue the performance of measurement.

2.3.7 Performance of Measurement

(1) Measurement should be performed and managed by a dedicated team.

(2) The person in charge of measurement should be a civil engineer (soil and foundation) who can understand the characteristics of the measurement instruments and the behavior of slope surfaces.

2.3.8 Measurement Frequency

(1) It is inappropriate to determine a generally applied measurement frequency. The measurement frequency should be determined based on the conditions of each slope surface, the construction site conditions, and an expert analysis.

(2) When slope surface conditions are changed, the measurement frequency should be increased to secure the safety of workers.

(3) The normal measurement frequency is in principle maintained after the completion of construction works or after preventive construction works.

(4) Collapse or sliding of slope surfaces is often caused by external factors such as torrential rain, melting of snow, and earthquake. In the presence of such a factor, the measurement frequency should be increased to monitor the slope surface behavior, regardless of the measurement frequency determined by the previous measurement plan, while performing surveillance and checkup after a torrential rain or an earthquake.

(5) When manual measurement is performed, the slope surface measurement frequency may be determined by referring to Table 2.3-1.

Table 2.3-1 Measurement frequency goals in manual measurement of slope surfaces.

<table>
<tr><th rowspan="2">Subject of Measurement</th><th rowspan="2">Measurement Instrument</th><th colspan="5">Measurement Frequency Goals (for manual measurement)</th></tr>
<tr><th>Survey and planning stage</th><th>Construction stage</th><th>Maintenance stage</th><th>Effect judgment</th><th>Emergency</th></tr>
<tr><td rowspan="8">Change of ground surface (deformation, displacement)</td><td>Ground surface extensometer</td><td rowspan="2">3 to 4 times per year</td><td rowspan="2">1 time per day or 1 or 2 times per week</td><td rowspan="2">4 to 6 times per year</td><td rowspan="2">1 or 2 times per week or 1 time per month</td><td rowspan="2">1 or 2 times per day</td></tr>
<tr><td>Ground inclinometer</td></tr>
<tr><td>Changeover switch</td><td rowspan="2"></td><td rowspan="2">Ongoing</td><td rowspan="2">Ongoing</td><td rowspan="2">Ongoing</td><td rowspan="2">Ongoing</td></tr>
<tr><td>Detection line-type rock fall detector</td></tr>
<tr><td>Peg-moving measurement</td><td rowspan="2"></td><td rowspan="2">1 time per day or 1 or 2 times per week</td><td rowspan="2">4 to 6 times per year</td><td rowspan="2">1 or 2 times per week or 1 time per month</td><td rowspan="2">1 or 2 times per day</td></tr>
<tr><td>Ground surface settlement measurement</td></tr>
<tr><td>GPS measurement</td><td></td><td colspan="4">Measurement may be performed 1 to 2 times per day by installing a receiver. No measurement frequency standard is currently available. The main measurement target is the horizontal movement of the ground surface. The goal is for measurement frequency to be as often as peg-moving measurement frequency.</td></tr>
<tr><td rowspan="3">Underground change (deformation, displacement)</td><td>Underground inclinometer</td><td>3 to 4 times per year</td><td rowspan="3">1 time per day or 1 or 2 times per week</td><td rowspan="3">4 to 6 times per year</td><td rowspan="3">1 or 2 times per week or 1 time per month</td><td rowspan="3">1 or 2 times per day</td></tr>
<tr><td>Fixed-type underground inclinometer</td><td></td></tr>
<tr><td>Underground displacement meter</td><td></td></tr>
<tr><td rowspan="2">External force applied</td><td>Earth pressure gauge</td><td rowspan="4"></td><td rowspan="4">1 time per day or 1 or 2 times per week</td><td rowspan="4">4 to 6 times per year</td><td rowspan="4">1 or 2 times per week or 1 time per month</td><td rowspan="4">1 or 2 times per day</td></tr>
<tr><td>Load gauge</td></tr>
<tr><td rowspan="2">Internal stress</td><td>Deformation gauge</td></tr>
<tr><td>Rock bolt, nailing axial force gauge</td></tr>
<tr><td rowspan="4">Deformation and displacement of structures</td><td>Inclinometer for structure surface</td><td rowspan="4"></td><td rowspan="4">1 time per day or 1 or 2 times per week</td><td rowspan="4">6 to 12 times per year</td><td rowspan="4">1 or 2 times per week or 1 time per month</td><td rowspan="4">1 or 2 times per day</td></tr>
<tr><td>Light wave ranging</td></tr>
<tr><td>underground inclinometer</td></tr>
<tr><td>Crack gauge</td></tr>
</table>

Deformation (degradation)	IR thermal imaging (Remote sensing technique)		When necessary	When necessary	When necessary	When necessary
Change of groundwater level and pressure	Water level meter	Daily self-recorded observation	Daily self-recorded observation	Daily self-recorded observation	Daily self-recorded observation	Daily self-recorded observation
	Pore water pressure gauge					
Meteorological data	Rain gauge	Daily self-recorded observation				
	Snow depth gauge	Observed when necessary	Observed when necessary	Observed when necessary	Observed when necessary	Observed when necessary
Groundwater drainage effect	Flowmeter	Daily self-recorded observation	Daily self-recorded observation	Daily self-recorded observation	Daily self-recorded observation	Daily self-recorded observation
※ The measurement frequency should be increased when there are abnormal meteorological conditions, including thaw, rain and typhoon, or during earthquakes.		To decide the risk at positions that have been identified as particularly requiring observation in the preliminary survey	On-site measurement performed before construction works to secure safety of preventive construction or the main construction works.	To take emergency actions to secure the safety of the targets to be preserved or human life	To verify the effect of preventive construction works against slope surface collapse	In cases of collapse or change of slope surfaces during construction works or in the maintenance stage

2.3.9 Measurement Period

(1) An appropriate measurement period, without excess or shortage, should be established by considering the purposes of measurement, the risk of slope surface collapse or landslide, the type of collapse, the characteristics and arrangement of measurement instruments, and the site conditions (particularly the structures to be preserved).

(2) The measurement period should be determined according to the scale and effect of slope surface change, the importance of the structures to be preserved, the presence of preventive construction works, and the slope surface facilities. Since the change in the slope surface is greatly dependent on the meteorological factors, including rainfall and the melting of snow, measurement needs to continue for at least one year, as this is the necessary and optimal period to investigate the behavior accurately.

(3) For a slope surface identified in the preliminary site survey and rock survey as a risky slope surface, the measurement should be initiated even before the start of the construction works (for the investigation and interpretation of deformation mechanism, the assessment of slope surface stability, the comparison with analytical results, and the implementation of information technology-based construction works, etc.).

(4) Measurement should be initiated following the preventive construction works (for the verification of the preventive construction method, the establishment of an auxiliary preventive construction method, and the reverse analysis of the results, etc.).

(5) Measurement should be initiated after deformation of the slope surface has been visually observed (for investigation and interpretation of the deformation mechanism, assessment of slope surface stability, construction work management, establishment of a preventive construction method, reverse analysis of the results, and prediction of collapse, etc.).

(6) Measurement is complete when no further change in the slope surface is observed. Subsequently, the measurement should continue for one year to investigate the effects of the melting of snow, rainy season, typhoon, and autumn rain on the slope surface. In the meantime, the measurement may be deemed as complete after verifying that no change has been observed.

2.3.10 Summary and Analysis of Measurement Result

(1) The project title, position, name of slope surface, measurement points, measurement items, measurement locations, measurement date and time, and name of measurement worker should be written on all measurement result recording sheets.

(2) The measurement result should be analyzed by a construction engineer who understands the ground behavior and has extensive experience in the design, construction, and measurement involved in cutting construction.

(3) If the analysis of the measurement results reveals any problem with the safety of the slope surfaces, an appropriate emergency action should be taken, and the cause should be investigated in order to prepare a reinforcement countermeasure.

2.3.11 Measurement Management Standard

(1) Since measurement management standards are determined by the behavior of the ground, the safety limits of adjacent structures, and the conditions of rock mechanics, the reference values are difficult to clearly present. As such, the most reasonable and practical method is to continuously modify the management standards on the basis of the initial construction results by referring to the theoretical analysis, numerical analysis, and construction results under similar conditions.

(2) The measurement management standard is the safe level of measurement results. The specific values of the measurement management standard should be determined after considering the slope surface characteristics, on-site situation, and possible damages.

2.3.12 Report of Measurement Result

Must conform to 1.3.12.

3. Foundation Construction

3.1 General

3.1.1 Scope of Application

(1) This standard is applied to measurement for the quality control of the pile foundation and caisson foundation, and the management of verticality.

(2) Measurement management for any purpose other than those described in (1) above will be described separately.

3.2 Materials

3.2.1 Types of Measurement Instrument

(1) The tube for soundness testing should have a diameter of 30 to 50 mm, and the material should be steel or another material having similar strength.

(2) The precision of the displacement meter should be within 1/100 mm.

3.2.2 Other

The measurement instrument should be a product that is appropriate for the installation conditions.

3.3 Construction

3.3.1 Installation of Measurement Instrument

(1) The displacement meter should be installed on a fixed board at a position that is not affected by the pile settlement and vibration.

(2) The inside of the measurement tube should be free from any damage caused by rust, or any obstruction. The connecting part should be completely waterproofed.

(3) The necessary number of measurement tubes should be bound in a steel reinforcement net and installed for all piles.

3.3.2 Correction of Measurement Instrument

(1) The normal operation of a measurement instrument should be tested before and immediately after the installation. If necessary, the measurement instrument should be calibrated.

(2) If the measurement value is changed unusually during the measurement, the normal operation of the measurement instrument should be checked. If necessary, the measurement instrument should be calibrated.

3.3.3 Protection of Measurement Instrument

The measurement instruments should be protected during measurement to avoid any effect from various construction machines and operators.

3.3.4 Installation of Data Transmission Cable

The measurement instrument cable should be a cable that is exclusively for the measurement instrument. A single cable with no connection point from the laying point to the measurement room should be used.

3.3.5 Inspection and Testing According to Measurement System Installation

Following the installation works for measurement, the correction and tests should be performed, and a test-run should be implemented.

3.3.6 Management of Measurement Instrument

The measurement instruments should be protected during the measurement to avoid the effect of various construction machines and operators.

3.3.7 Performance of Measurement

(1) Piling Works

① Measurement should be performed to measure the maximum number of hits for the completion of the piling works.

② The rebound should be measured for all piles to calculate the supportive force using the dynamic supportive force equation.

(2) Soundness and Verticality

① The obstruction of the measurement tubes should be checked, and the front-end depth should be measured to verify the measurement depths in the individual paths. If there is a significant difference in the front-end positions between the measurement tubes, the measurement should be performed separately with respect to the front-ends.

② Measurement should be performed continuously by pulling up the transmitting sensor and the receiving sensor from the front-end of the pile, while keeping the sensors on the same plane perpendicular to the length direction of the pile.

③ Measurement should be performed for all possible path combinations depending on the number of installed measurement tubes.

④ A protective cap should be installed on the tubes to prevent any impurity after the completion of the measurement, and should remain installed until the superintendent makes a decision about the testing.

⑤ The vertical deviation of existing piles should be less than 1/100. After completion of the

piling works with the existing piles, the positions on the floor plan should be kept within the larger value of D/4 (D is the diameter of the existing pile.) and 100 mm.

(3) Settlement of Caisson Foundation

① During the caisson settlement, real-time measurement of the caisson slope should be performed.

② When a significant eccentricity or inclination occurs during settlement, the causes should be immediately investigated and reported to the superintendent to prepare countermeasures to apply to future construction works.

3.3.8 Measurement Frequency

(1) The measurement frequency for the quality control of piles should be the frequency specified in the design drawings.

(2) The frequency of measuring the slope of a caisson foundation should be sufficient to investigate the caisson slope not only at the start and end of the settlement of the individual segments but also during the settlement.

3.3.9 Summary and Analysis of Measurement Result

After the completion of measurement, the measurement should be reviewed by a specialized engineer, and the construction worker should immediately submit the testing reports for each testing pile to the superintendent.

3.3.10 Measurement Management Standard

The measurement management standard should conform to the quality control standard specified in the construction specifications.

3.3.11 Report of Measurement Result

Must conform to 1.3.12.

4. Water and Sewer Construction

4.1 General

4.1.1 Scope of Application

(1) The purpose of monitoring management presented in this standard is for safety and quality control during the water and sewer construction.

(2) Monitoring management for any purpose other than the one described in (1) above will be planned separately.

4.2 Materials

Not applicable.

4.3 Construction

4.3.1 Installation of Measurement Instrument

(1) Overview of Installation

① The person in charge of monitoring should install the monitoring instruments accurately according to the procedures specified in the manuals provided by the manufacturers.

② The installed monitoring instrument should be protected from the construction works and other effects, to avoid damages.

(2) Measurement of water leakage: Water leakage measurement instruments should be installed in more than or equal to 50% of sewer pipes (wastewater pipes) with a diameter less than 800 mm for each pipe diameter before backfilling.

(3) Water pressure measurement: A water pressure measurement instrument should be installed for pressure pipes after pipe installation and before backfilling.

(4) Radiographic measurement: A radiographic measurement instrument should be installed after the welding of steel pipes.

(5) Ultrasonic detection measurement: An ultrasonic detection measurement instrument should be installed after the welding of steel pipes.

(6) Pressure measurement at welding parts: A pressure measurement instrument should be installed after the welding on the inside and outside of steel pipes is completed.

(7) Potential measurement: A potential measurement instrument should be installed at locations where electrolytic corrosion should be prevented after the installation of water pipes.

(8) Measurement of flow distribution and head loss: A measurement instrument for the flow distribution and head loss should be installed after construction of underdrains.

(9) Measurement of allowable load carrying capacity: A measurement instrument for the allowable load carrying capacity should be installed after completing the equipment assembly.

4.3.2 Correction of Measurement Instrument

(1) A monitoring instrument should be tested before and immediately after installation to ensure its normal operation. If necessary, the monitoring instrument should be calibrated.

(2) If the measurement value is changed unusually during the monitoring, the normal operation of the monitoring instrument should be checked. If necessary, the monitoring instrument should be calibrated.

4.3.3 Management of Measurement Instrument

(1) The monitoring instrument should be managed according to the methods and procedures provided by the manufacturers to maintain the performance and secure the reliability of the monitoring results.

(2) In cases where a monitoring instrument has been damaged by blast or other causes, another monitoring instrument should be installed at an adjacent position to continue the monitoring.

4.3.4 Performance of Measurement

(1) Overview

① Monitoring should be performed and managed by a dedicated team.

② The person in charge of monitoring should be an expert in construction-related field who understands the characteristics of the measurement instruments and has extensive experience in the field of water and sewer system, or an engineer specialized in the nondestructive testing of steel materials.

(2) Measurement of Water Leakage

① A rubber plug (cylinder type) is installed at the lower part of the pipe.

② Air is injected to the inside of the rubber cap using a compressor.

③ A brace is installed to prevent movement of the pipe or the rubber cap by water pressure.

④ Another rubber plug (air release type) is installed at the upper part of the pipe line (the air-releasing pipe installed at the upper part of the plug, and the water-injecting pipe at the lower part) and fixed by injecting air.

⑤ A water tank and a water-injecting pipe are appropriately connected with hoses.

⑥ A vertical testing pipe and an air-releasing pipe are connected with hoses (The vertical testing pipe should be located to maintain the distance from the upper end of the pipe in the inside to the water head of the vertical testing pipe as 1 m.).

⑦ The valves attached to the water-injecting pipe and the air-releasing pipe are opened, and the water from the water tank is slowly supplied to the inside of the pipe to prevent the formation of air bubbles.

⑧ When the inside of the pipe starts to be filled with water and the water starts to come out through the air-releasing pipe, a small amount of water is discharged and the valve attached to the air-releasing pipe is then closed.

⑨ Water is continuously injected to the pipe. If the vertical testing pipe overflows, the valve of the water-injecting pipe is closed.

⑩ The pipe is left for at least 30 minutes until it is saturated. Then, water is supplied to keep the water head of the vertical testing pipe at the upper end of the pipe in the inside at a level of 1 m (If a large amount of water is continuously diminished, the work

should be stopped to check for abnormal pipe conditions).

⑪ Water leakage should be measured at five minute intervals after filling the vertical testing pipe to the top with water.

⑫ The results of the water leakage test should be attached to the construction completion documents.

(3) Water Pressure Measurement

① Before injecting water for water pressure testing, the pipe line should be temporarily back filled to prevent it from being moved during the water pressure testing.

② When injecting water into the pipe line, it should be injected slowly while removing any air in the pipe. The removal of air from the air valves or the abnormality of the pipe should be checked while filling water. For locations where water leaks, appropriate measures should be taken to stop the leakage.

③ After filling the pipe with water, the pipe should remain filled for at least 24 hours to remove all the air inside the pipe. The water pressure testing should be performed after the lining, including the cement mortar, is sufficiently saturated. The specified water pressure should be maintained for 24 hours to check for any abnormality in the pipe and to measure the water leakage.

④ For connections in pipes with a diameter greater than or equal to 800 mm, the water pressure testing should in principle be performed using a test band from the inside of each connection in the presence of the superintendent.

⑤ During the water pressure testing using the test band, the water pressure should be kept greater than or equal to 0.5 MPa (N/mm2) for five minutes and should not drop below 0.4 MPa (N/mm2). If the water pressure drops, the water pressure testing should be performed after connecting the pipes again.

(4) Ultrasonic Detection Testing

Ultrasonic detection testing of on-site welded connections should conform to KS B 0817, KS B 0888, KS B 0896, and KS D 0252.

(5) Radiographic Measurement

Radiographic measurement should be performed after acquiring the approval of the superintendent with regard to the testing method, processes, and report preparation format.

(6) Pressure Measurement at Welding Parts

① Following the completion of the welding works on the inside and outside the pipes, after the heat is completely released from the welding parts, the impurities should be removed and a pressure gauge should be attached at the test hole of the welding point.

② After attaching a pressure gauge, the pressurized gas container should be gradually opened until the pressure at the pressure gauge reaches 1.5 MPa (N/mm2).

③ After keeping the pressure at 1.5 MPa (N/mm2) for at least 10 minutes, a check for

leakage should be performed. At the air-leaking point, welding should be performed again after completely removing the weld deposits and testing should be repeated.

④ After the air-tightness testing is completed, the pressure gauge is removed and the test hole is welded.

⑤ If construction site conditions make it impossible to achieve the specified air-tightness testing period, appropriate actions must be taken based on the instructions of the superintendent. Photos should be taken at the welding points that have passed the air-tightness testing by keeping the pressure at 1.5 MPa (N/mm2). Then, the points should be covered according to the directions of the superintendent.

(7) Measurement of Potential

① Self-potential should be measured when no current is applied to the target material for cathodic protection. If a current has been applied, the measurement should be performed after the effect of the applied current has completely dissipated.

② Cathodic protection potential should be measured at least 24 hours after the current application.

③ The reference value of the cathodic protection potential should be less than or equal to -0.85 V for a saturated copper sulfate reference electrode. The lower limit of the cathodic protection potential should be greater than or equal to -2.5 V for a saturated copper sulfate reference electrode, except in areas subject to external interference such as underground railways.

④ The minimum potential change caused by cathodic protection current should be less than or equal to -300 mV from the self-potential.

⑤ The test and inspection of cathodic protection should include the following items:

a. Insulation resistance measurement according to KS C 1301 and KS C 1302

b. Withstand voltage testing according to KS C 8536

c. Laboratory test method of sacrificial anodes for cathodic protection according to KS D 0235

(8) Measurement of Flow Distribution and Loss of Head

① Measurement of flow distribution in lower catchment (water)

a. The underdrain of each filter should be checked to determine whether any of the orifices are blocked by impurities. An outflow distribution test should be performed to visually verify the uniform distribution of the flow.

b. The test should be performed before the filter medium is placed. When the test is initiated, the underdrain should be filled with water up to about half of its height.

c. The average backwashing speed during the flow speed test should exceed the speed specified in the design. The flow speed should be measured for about two minutes to allow for a visual observation.

d. The flow distribution test should be performed three times repeatedly. In each test session, the flow from the individual orifices needs to be carefully observed as well as any existence of a discontinued flow or a discontinuing flow.

e. If a problem is found in the test that must be resolved, the appropriate action should be taken, and the test performed again to confirm that the problem has been resolved.

② Measurement of flow distribution in lower catchment (air)

a. The underdrain of each filter should be checked to determine whether any of the orifices are blocked by impurities. A outflow distribution test should be performed to visually verify the uniform distribution of the flow.

b. If a problem is found in the test that must be resolved, the appropriate action should be taken, and the test performed again to confirm that the problem has been resolved. For the test after the placement of the filter medium, the underdrain should be filled with clean water to a height about 30 cm higher than the top of the underdrain.

c. The test flow speed should be measured for two minutes at a normal backwashing speed of air and water.

d. The flow distribution test should be performed three times repeatedly. In each test session, the flow from the individual orifices needs to be carefully observed as well as any existence of a discontinued flow or a discontinuing flow.

e. If a problem is found in the test that must be resolved, the appropriate action should be taken, and the test performed again to confirm that the problem has been resolved.

③ Measurement of loss of head

The head loss in the system should be measured with at least one filter. The measured frictional head loss is applied to lower waterways, cross pipes, underdrains, and filter medium supporting systems.

(9) Measurement of allowable load carrying capacity

① The operation of the instrument should be tested after completing the equipment assembly.

② For the deployment of the equipment, an equipment entry plan, including the details of equipment transportation, equipment entry method, crane size, and safety measures, should be submitted two months before the excavation at the project area begins.

4.3.5 Measurement Frequency

(1) Water leakage measurement: Measurement should be performed at least once before the back filling of the pipelines and at least once after pavement works.

(2) Water pressure measurement: Measurement should be performed at least once before the back filling of the pipelines and at least once after pavement works.

(3) Ultrasonic detection measurement: Measurement should be performed at least once after the welding of steel pipes and before the backfilling.

(4) Radiographic measurement: Measurement should be performed at least once after the welding of steel pipes and before the backfilling.

(5) Pressure measurement at welding parts: Measurement should be performed at least once after the welding of the inside and outside of steel pipes and before the backfilling.

(6) Measurement of potential: Measurement should be performed at least once after the installation of the water pipes for the pipelines that require the measurement of potential.

(7) Measurement of allowable load carrying capacity: Measurement should be performed at least once after the equipment assembly.

(8) Measurement of flow distribution and head loss: Measurement of flow distribution and head loss should be performed at least once after the installation of underdrains and before the placement of filter medium for each filter.

4.3.6 Summary and Analysis of Measurement Result

(1) The project title, project location, name of facility, measurement points, monitoring parameters, monitoring locations, measurement date and time, and name of the person who conducted the measurement should be recorded on all the monitoring result data sheets.

(2) The monitoring result should be analyzed by an engineer in construction-related industry with extensive experience in water and sewer area or relevant area.

(3) If the analysis of the monitoring result shows that the water and sewer facilities have a problem, an appropriate emergency action should be taken and the causes should be investigated to prepare a permanent solution.

(4) After the completion of monitoring, the monitoring result should be summarized and submitted to the superintendent for verification to carry out the subsequent works.

4.3.7 Measurement Management Standard

(1) The criteria for monitoring management may be changed or adjusted with the approval of the relevant expert or relevant authorities and institutions depending on the site conditions and circumstances.

(2) Water leakage measurement: If the reduction of the water in the vertical testing pipe, after filling it with water, during a 10 minute period is less than the allowable water leakage amount, the test

is passed.

(3) Water pressure measurement: The allowable water leakage is dependent on the pipe type, pipe diameter, and connection type. For a socket-connected pipe with a rubber ring, the standard allowable water leakage is 50~100ℓ/day per 10 mm in pipe diameter and per 1 km in pipe length.

(4) Radiographic measurement: The radiographic measurement standard conforms to KS B 0845. If the defect is a Type 1 defect or over Grade 3 of a Type 2 defect, the test is passed.

(5) Ultrasonic detection measurement: The defects are evaluated based on the defect length classified as A, B, and C values in Table 4.1 depending on the thickness of the parent material and based on the maximum echo height shown in Table 4.2. If the defect evaluation score is equal to or less than 3 points and the sum of the evaluation score per the welding length of 30 cm in the area where the defects are most dense is equal to or less than 5 points, the test is passed.

Table 4.3-1 Classification of defect length in ultrasonic detection test.

Defect length class / Parent material thickness (mm)	A	B	C
Between 6 and 18	6	9	18
Over 18	t/3	t/2	t

Note 1) t: thickness of parent material plate. For butt welding with plates of different thicknesses, t is the thickness of the thinner one.

Table 4.3-2 Defect evaluation point in ultrasonic detection test.

Defect length / Max. echo height (mm)	Below A	Between A and B	Between B and C	Over C
Domain Ⅲ	1	2	3	4
Domain Ⅳ	2	3	4	4

(6) Measurement of allowable load carrying capacity: The allowable load carrying capacity in the longitudinal direction is shown in Table 4.3-3.

Table 4.3-3 Allowable load carrying capacity in forward direction

Diameter	Allowable load carrying capacity		Effective cross-sectional area A (㎡)
	500(N/㎟)	700(N/㎟)	
800	23.0		0.1766
900	29.9		0.2297
1,000	37.7		0.2897
1,100	43.8		0.3365
1,200	53.1		0.4084
1,350	62.4		0.4800
1,500	79.4		0.6107
1,650	94.5		0.7270
1,800		149.3	0.8533
2,000		183.6	1.0494
2,200		221.5	1.2658
2,400		255.3	1.4590
2,600		299.7	1.7123

4.3.8 Report of Measurement Result

Must conform to 1.3.12.

5. Tunnel Construction

5.1 General

5.1.1 Scope of Application

(1) The purpose of monitoring management presented in this standard is for safety management during tunnel constructions.

(2) Monitoring management for purposes other than the one described in (1) above is planned separately.

5.2 Materials

5.2.1 Measurement Instruments

(1) The measurement error of the surface and subsurface settlement gauge should be within ± 1 mm.

(2) The measurement error of the tunnel convergence and arch settlement measuring system should be within ± 1 mm.

(3) The measurement error of the subsurface displacement gauge should be within ± 0.1 mm.

(4) The accuracy of the load cell for rock bolt axial force should be over 0.1 kN.

(5) The accuracy of the pressure cell for shotcrete stress should be over 0.01 MPa.

(6) The precision of the instrument used to measure the preceding displacement ahead of the tunnel face should be over ± 0.1 mm/m.

(7) The center hole jack for the rock bolt pull-out test should have a capacity over 30 kN and a level of precision within 5 kN, and the precision of the displacement gauge should be within 1/100 mm.

5.2.2 Measurement Data Acquisition System

Generally, the automated monitoring management methods include a semi-automated monitoring management method in which the recording of the measurement data on a recording sheet or a data storage device is performed automatically and the subsequent processing is performed using a computer, a fully-automated monitoring management method in which data collection, analysis, and plotting are comprehensively performed using a wired or wireless on-line system, and a composite method combining the two methods above. The data acquisition system should be selected considering the conditions of the slope surfaces to be monitored.

5.3 Construction

5.3.1 Installation of Measurement Instrument

(1) Surface and Subsurface Settlement Gauge

Surface and subsurface settlement gauge should be installed at the time the initial values may be measured before the tunnel face is reached at a position where the distance between the tunnel face and the gage location becomes three times the tunnel diameter. However, if the effect of tunnel excavation is expected to extend more than three times the tunnel diameter due to the ground conditions including a special ground type, the gauges should be installed before any displacement occurs to measure the initial values.

(2) Tunnel Convergence and Arch Settlement Measurement Instrument

The measurement points for tunnel convergence and arch settlement should be installed immediately after placing the sealing shotcrete and before the tunnel excavation advances further to measure the initial values and, therefore, to fully capture the displacements caused by the further excavation.

(3) Subsurface Displacement Gauge

① The subsurface displacement gauges should be firmly anchored to the ground so that the ground movement is sufficiently reflected.

② To measure the initial values, the subsurface displacement gauges should be installed immediately after placing the primary shotcrete and before the excavation advances to the next tunnel face to measure the initial values and, therefore, to fully capture the displacements caused by the further tunnel excavation.

(4) Load Cell for Rock Bolt Axial Force

① Load cell for measurement of rock bolt axial force should be installed immediately after placing the primary shotcrete and being sufficiently attached to the ground and before the excavation advances to the next tunnel face to measure the initial values and, therefore, to fully capture the change of the axial force caused by the further tunnel excavation.

② Load cell for measurement of rock bolt axial force should be firmly fixed on the ground so that the change of the axial force caused by the ground displacement at the measurement positions may be sufficiently reflected.

③ The material, specifications, and filling materials of the rock bolts for the measurement of the axial force should be the same as the rock bolts used for actual construction.

(5) Pressure Cell for Shotcrete Stress

① Pressure cell for shotcrete stress should be installed at the time of shotcrete placement and before the excavation advances to the next tunnel face to measure the initial values and, therefore, to fully capture the change of the axial force caused by the further tunnel excavation.

(6) Measurement Instrument for Preceding Displacement Ahead of Tunnel Face

① The instrument to measure the preceding displacement ahead of tunnel face should be installed on the front of the tunnel before the excavation advances further to measure the initial values and, therefore, to recognize the settlement of the ground ahead of the tunnel face.

② It should be installed on the same line as for the arch settlement measurement so that the measured vertical settlement can be compared each other.

③ The drilling angle for the measurement instruments is desired to be 7° to 10° upward to consider the interference with the deflection angle of drilling and the implementation of an auxiliary method. The measurement instruments should not be damaged by the rock bolts or the construction works in the tunnel, including an auxiliary method.

④ The amount of displacement, which is based on the measurement of the preceding displacement, should be calculated as the cumulative displacement with reference to the innermost part of the drilling hole (Measurement Instrument No. 1). Therefore, the installation length of the measurement instruments should be sufficiently long to prevent any error resulting from a displacement.

5.3.2 Correction of Measurement Instrument

(1) The normal operation of a monitoring instrument should be tested before and immediately after installation. If necessary, the monitoring instrument should be calibrated.

(2) If the measurement value is changed unusually during the monitoring, the normal operation of the

monitoring instrument should be checked. If necessary, the monitoring instrument should be calibrated.

(3) In principle, the monitoring equipment should be tested and calibrated on a regular basis at a national certification institution or other institution with equivalent qualifications. However, if there is no national certification institution for a specific monitoring equipment or if a monitoring equipment is based on new technology, testing and calibration may be performed according to the manufacturer's manual.

5.3.3 Protection of Measurement Instrument

The installed monitoring instrument should be protected from the construction works and other effects, to avoid damages.

5.3.4 Management of Measurement Instrument

(1) To maintain the performance and secure the reliability of the monitoring results, the monitoring instrument should be managed according to the methods and procedures provided by the manufacturers.

(2) A sufficiently high level of illumination should be maintained around a monitoring instrument installed inside a tunnel to manage the monitoring instrument and to conduct the monitoring. A signboard on which the title of monitoring, location, initial measurement date, and initial measurement values are written should be installed for management.

(3) In cases where a monitoring instrument has been damaged by blasting or other causes, another monitoring instrument should be installed at an adjacent position to continue the monitoring.

5.3.5 Performance of Measurement

(1) Execution and management of monitoring may be carried out by a dedicated monitoring team operated by the contractor, or may be entrusted to a specialized monitoring company.

(2) The person in charge of monitoring should be an engineer who understands the characteristics of the monitoring instruments as well as the behavior of the ground and tunnel support structures caused by the tunnel excavation, and who has majored in geotechnical engineering, geology or other relevant subjects.

5.3.6 Monitoring Frequency

(1) Convergence, arch settlement, subsurface displacement, and rock bolt

① The frequency of measuring the convergence and arch settlement should be determined based on the displacement rate or the distance from the tunnel face, as shown in Table 5.3-1, and may be adjusted according to the displacement trend.

Table 5.3-1 Frequency of measuring tunnel displacement and crown settlement.

Measurement frequency	Displacement speed	Face distance	Note
Twice per day	Over 10 mm per day	0D ~ 1D	D is the tunnel diameter.
Once per day	10 to 5 mm per day	1D ~ 2D	
Once per two days	5 to 1 mm per day	2D ~ 5D	
Once per week	Below 1 mm per day	Over 5D	

(2) Frequency of measuring surface and subsurface settlement

① The frequency of measuring the surface and subsurface settlement should be determined after considering the distance from the tunnel face, excavation advance rate, and the behavior of the ground and tunnel support structures, and may be properly adjusted depending on the monitoring results by referring to the following standard:

a. Section for 3D ahead of tunnel face ~2D ahead of tunnel face: 1 time/2 days
b. Section for 2D ahead of tunnel face ~1D behind tunnel face: 1 time/1 day
c. Section for 1D behind tunnel face ~3D behind tunnel face: 1 time/2 days
d. 3D behind tunnel face ~Until displacement convergence: 1 time/3 days
e. D denotes the tunnel diameter.

(3) The monitoring parameters and frequency may be changed based on the site conditions and ground conditions with the approval from the superintendent.

5.3.7 Monitoring Period

(1) The measurement period for monitoring during tunnel construction is from the installation of monitoring instruments to the confirmation of the convergence of the measurement values.

5.3.8 Summary and Analysis of Measurement Result

(1) The project title, project location, name of tunnel, measurement points, monitoring parameters, monitoring locations, measurement date and time, and name of the person who conducted the measurement should be recorded on all the monitoring result data sheets.

(2) The monitoring results should be summarized for each of the measured parameters in the predetermined format, and must include the measurement date, number of days elapsed, distance from the tunnel face (for upper half and for lower half separately), initial values, displacement measured at the current measurement, and cumulative displacement. Graphs showing Time (number of days elapsed) versus Measured value and Distance from the tunnel face versus Measured value should be prepared so that the engineer can rapidly understand the trend of the measured values and apply them to subsequent construction works.

(3) The monitoring result should be analyzed under the supervision of the person in charge of the

monitoring by an engineer who understands the ground behavior, has majored in an area related to geotechnical engineering, and has extensive experience in tunnel construction.

(4) The person in charge of monitoring should perform analysis by referring to the numerical analysis results conducted for the project site or other sites with similar conditions, the empirical values, other measurement results, and the ground conditions of the project site. The reference values for monitoring management criteria are established by considering the absolute change and the rate of change of the measurement values, and the stability is evaluated using the reference values. In addition, if the management criteria based on the displacement predicted in the design stage are applied, the evaluation of stability and the implementation of preventive construction works (including the change of the support patterns) should be carried out by preparing reasonable countermeasures through a comprehensive consideration of all relevant measured parameters (support stress, axial force, etc.) rather than the consideration of the monitoring results from a single monitoring item only. The reference values for monitoring management criteria should be established after acquiring approval from the superintendent.

(5) If the analysis of the monitoring result shows a problem with tunnel safety, a superintendent should request a contactor to take an appropriate emergency action and then to seek for a permanent solution after investigating the causes.

(6) After the completion of monitoring, the monitoring result should be summarized and submitted to the superintendent for verification to carry out the subsequent works.

5.3.9 Measurement Management Standard

(1) Because the criteria for monitoring management are determined by the conditions of the ground behavior, the safety limits of adjacent structures, and the factors based on rock mechanics, the reference values for the criteria are difficult to be clearly prescribed. Therefore, the most reasonable and practical approach is to regularly modify the criteria on the basis of the initial construction results with reference to the theoretical analysis, numerical analysis, and the construction results under similar conditions.

(2) The primary criterion is to establish construction management goals. The secondary criterion is to be prepared for potential effects on the adjacent structures. The tertiary criterion is to be prepared for the risk on the tunnel itself.

5.3.10 Report of Measurement Result

Must conform to 1.3.12.

6. Dam Construction

6.1 General

6.1.1 Scope of Application

(1) The purpose of monitoring management presented in this standard is for safety control and quality control during dam construction.

(2) Monitoring management for purposes other than the one described in (1) above is planned separately.

6.2 Materials

6.2.1 Types of Measurement Instruments

(1) Measurement error of the instrument used to measure the external deformation on the surface of the dam body should be within ± 1.0 mm.

(2) Measurement error of the instrument used to measure the settlement occurring inside the dam body should be within ± 1.0 mm.

(3) The measurement range for the no-stress strain due to the change of concrete temperature should be greater than or equal to 3,000με, and the resolution should be less than or equal to 0.1με.

(4) The inclinometer installed on the slope surface of the face slab should have the capacity to measure inclination over ± 90°, and the vertical inclinometer installed at the center of the dam over ± 50°.

(5) For a concrete-faced rockfill dam, the displacement gauge measuring displacements in three directions at the joint between the face slab and the plinth should have the measurement range of at least 100 mm and the measurement error should be within ± 0.01 mm.

(6) The instrument used to measure the stress of the concrete face slab should in principle be installed using rosette blocks with three instruments as one set, in the directions of 0°, 45°, and 90°.

(7) The pore water pressure measurement range should be planned by considering the pore water pressure specified in the design and should fundamentally be over 1 MPa.

6.2.2 Monitoring Data Acquisition System

(1) In the dam performance monitoring, it is critical to detect early signs in order to prevent or minimize damages not only during construction but also for maintenance. The information should be rapidly transmitted and processed immediately after the monitoring, and an automated measurement system should in principle be used to collect, process, and analyze the monitoring

data comprehensively.

(2) The automated data acquisition system should be able to transmit the monitoring data obtained from the instruments to the computers in a remote measurement room to allow the storage and analysis of the monitoring data by a remote computer. The automated data acquisition system should in principle allow manual measurement when necessary.

(3) The automated data acquisition system should be able to remotely control the monitoring instruments at each locations to change the measurement frequency.

(4) When an automated data acquisition system is used, a power supply device should be installed for the stable acquisition, storage, and transmission of monitoring data. In addition, accessories such as a voltage stabilizer, a dehumidifier, a device for constant temperature, and a lightning protection device should be installed, and, if necessary, a vibration-proof device should be prepared to avoid the effect of vibration.

6.3 Construction

6.3.1 Installation of Measurement Instrument

(1) For a homogeneous dam, the cables for individual instruments should be installed at the downstream measurement room by minimizing the cable length. For a zone dam, the cables should in principle be installed on either the left abutment side or the right abutment side after passing the same zone.

(2) The lead cables connecting the instruments and the circuit link lines, either buried in the rock layer, soil layer or concrete or exposed, should be reinforced, water-proofed, corrosion-protected, and insulated against tension, external forces, impacts, and lightning to accurately transmit the information from the individual instruments. The lead cables buried in the dam foundation and the dam body should be reinforced by using steel wires.

(3) The instruments and lead cables buried in the dam body or other structures should be tested immediately after the installation. Concrete placement or back filling should be performed only after normal operation is verified by the test.

(4) The inclinometers installed in the core wall of the dam body should be installed at each construction stage and connected with each other. The horizontal and vertical accuracy of the top center of the tubes installed in the previous construction stage should be within ± 1.0 mm.

(5) The stress and deformation measurement instruments for a dam body should be installed based on the following methods:

① Trench excavation should be performed to a depth of at least 1 m to install an earth pressure cell.

② At least the 30 cm-lift of the bottom of the trench should be compacted by using a manual tamper or a rammer. The upper part should be perfectly compacted in several

lifts before the back filling.

③ The slope of the excavation should be shallower than 1:1. The surface where the earth pressure is to be measured should be leveled in order to have no extruding part before the installation of the earth pressure cell.

④ The measurement surface of the earth pressure cell should be perpendicular to the earth pressure application direction and firmly fixed to be unmovable.

⑤ The pore water pressure measuring tip should be immersed in hydrostatic water for 24 hours before installation and kept away from direct sunlight. If the value on an indicator connected with the cable after immersion remains constant, suggesting the absence of any pores, the pore water pressure measuring tip should then be installed,.

(6) The concrete stress and deformation measurement instruments should be installed based on the following methods:

① The instrument used to measure the displacement of a vertical joint should be installed in two stages, during the placement of the primary concrete and the placement of the secondary concrete, so that the instrument may be buried in the vertical joint.

② Since the instrument is buried in concrete, it should be sealed by welding and undergo corrosion protection treatment.

③ The bottom surface of the instrument used to measure concrete stress should not be adhered to the concrete to avoid damages of the contact surface due to the concrete placement.

④ The no-stress strain gauge should be installed in the same location as the stress measurement instrument.

⑤ The no-stress strain gauge should be put into a specially designed container before it is buried. The gauge should be installed under the same temperature and humidity conditions as the surrounding concrete.

⑥ The no-stress strain gauge should not be separated from the contact surface due to the concrete placement, and concrete should be placed in stages into the container.

6.3.2 Correction of Measurement Instrument

(1) The normal operation of a monitoring instrument should be tested before and immediately after the installation. If necessary, the monitoring instrument should be calibrated.

(2) If the measurement value is changed unusually during the monitoring, the normal operation of the monitoring instrument should be checked. If necessary, the monitoring instrument should be calibrated.

6.3.3 Protection of Measurement Instrument

(1) A monitoring instrument that is partially exposed should be protected using an appropriate

protective device to avoid damage caused by construction equipment or people. A signage to indicate the presence of the instrument should be installed at a position that can be easily seen.

6.3.4 Installation of Data Transmission Cable

(1) The cable for monitoring data transmission should be of a type suitable for continuous monitoring. Plans should be established for placing the cable and for connecting and accessing the cable with respect to the communication protocols.

(2) The cable for monitoring instrument should be the one that is exclusively for the monitoring instrument. A single cable with no connection point from the installation location to the monitoring room should be used.

(3) The cable should be laid with sufficient slack to avoid tension in the cable due to the settlement of the monitoring instrument.

(4) The cables for all monitoring instruments should be protected by installing cable cover pipes.

(5) The cross-sectional area of the cable should not exceed 32% of the cross-sectional area of the cable cover pipe.

(6) The cover pipe should be used for the monitoring cable only. However, another cable that will not cause a disruption in communication for the monitoring cable may be used in the same pipe with the approval of the superintendent.

(7) The ends of the cable should be water-proofed to prevent the water infiltration from measurement to maintenance.

(8) The information about the type of the instrument, serial number, and cable type should be marked at the ends of the cable so that the cables may not be confused.

(9) When selecting, every equipment for data transmission should consider the compatibility in preparation for the potential need for future expansion and extension of monitoring system operation.

6.3.5 Inspection and Testing According to Measurement System Installation

(1) All instruments brought into the construction site to perform testing should have the test result reports from certification institutions. However, if approved by the Owner/Client, the reports may be replaced by the testing reports from the manufacturers.

① KS products according to the Industrial Standardization Act

② Products that have acquired the quality grade according to the Quality Control and Safety Management of Industrial Products Act

③ Telecommunications equipment that already obtained the type approval under Framework Act on Telecommunications

(2) After installing instruments for long-term or continuous monitoring, the calibration and testing should be completed and a test-run should be performed as follows.

① The person in charge of the installation of instruments is responsible for the primary test-run of the instruments under no-load conditions. After the completion of the test-run, the person in charge of for the installation of instruments should prepare a test-run result report and submit it to the superintendent.

② A comprehensive test-run, a test-run under loads, should be performed to test all the functions, including the comprehensive test-run with other facilities linked with the current instrument.

③ The test-run period should be at least 30 days.

6.3.6 Management of Measurement Instruments

(1) The monitoring instruments should be managed according to the methods and procedures provided by the manufacturers to maintain the performance and secure the reliability of the measurement results.

(2) A reliability evaluation should be performed with the monitoring instruments on a regular basis. The reliability evaluation should comprehensively consider the judgment on the changes with the passage of time, the judgment based on electrical examination, and the judgment based on the monitoring result including the behavior of a dam body.

6.3.7 Performance of Measurement

(1) Monitoring should be performed and managed by a dedicated team.

(2) The person in charge of monitoring should be an expert in construction-related field who understands the characteristics of the measurement instruments and the behavior of dam and ground.

6.3.8 Measurement Frequency

(1) The monitoring period during the construction works is divided into four stages as shown below, and the monitoring frequency is shown in Table 6.3-1. If the monitoring frequency has to be changed according to the measurement result, site conditions, and ground conditions, justifications for the change should be provided through the analysis of the monitoring data and the approval of the superintendent should be acquired before the change.

① Stage 1: For one month after the installation of instruments

② Stage 2: From one month after the installation of instruments to the completion of dam

③ Stage 3: In the event of anomalies in the measurement values, until the safety is verified

④ Stage 4: Flood control or one week after an earthquake

Table 6.3-1 Measurement frequency in dam construction

Measurement	Stage 1	Stage 2	Stage 3	Stage 4
Pore water pressure Groundwater level Internal settlement and differential settlement	Daily	Once per week	Daily	Daily
Adjacent joint displacement Horizontal displacement of vertical joint Dam structure and concrete strain Concrete stress-free strain Slope surface displacement	Daily	Once per week	Daily	Daily
External displacement and crest settlement	Daily	Daily	Daily	Daily
Automated measurement recording and computer control facility	Daily	Daily	Daily	Daily

(2) Since the results of the individual monitoring parameters need to be compared each other for analysis, the corresponding parameters should be measured in the same period, and parameters that need be measured at a higher frequency should be measured separately.

(3) In cases where an event that affects the dam stability occurs, including abnormal floods and earthquakes, measurement and analysis should be performed immediately to determine if there is any problem in the dam body and other structures. If there is a problem, a permanent countermeasure should be prepared.

6.3.9 Measurement Period

(1) The measurement period for monitoring during the dam construction is from the installation of the monitoring instruments to the completion of the construction. After that, the monitoring should be transferred to maintenance department.

6.3.10 Summary and Analysis of Measurement Result

(1) The project title, project location, name of dam, measurement points, monitoring parameters, monitoring locations, measurement date and time, and name of the person who conducted the measurement should be recorded on all the monitoring result data sheets.

(2) The monitoring results should be summarized for each of the measured parameters in the predetermined format and must include the measurement date, number of days elapsed, current status of construction works, initial values, measured values obtained at the current measurement, and changes of the measured values. Graphs for the analysis of the measured data should be prepared to show the change of each measured parameter over time at each

location and the distribution of the measured values of each parameters in the dam structure, so that the results may be utilized for construction management and safety control.

(3) The monitoring results should be analyzed by an engineer in construction-related field who is able to analyze the dam and ground behavior.

(4) If the analysis of the monitoring result shows a problem with the safety of the dam, an appropriate emergency action should be taken and the causes should be investigated to prepare a permanent solution.

(5) Analysis of dam stress and deformation measurement result

① The stress distribution in the dam body and the principal stress should be investigated based on the earth pressure measurement result to verify the appropriateness of the design and the stability of the dam body, and the possibility of hydraulic fracturing due to stress transfer needs to be checked.

② The deformation of the dam body should be analyzed based on the change over time, rate of change, and the presence of any differential settlement to determine the basic stability. The amounts of the settlement and the horizontal displacement should be measured simultaneously and used to assess the stability of the dam body after analyzing their mutual effects and the displacement at each construction height.

③ The measurement result obtained from the inclinometers installed on the concrete face slab should be analyzed together with the dam deformation measurements to review the possibility of the deformation and cracking of the concrete face slab.

(6) Analysis of concrete stress and deformation measurement result

① Areas where a tension is acting, such as perimetric joint of the concrete face slab, should be analyzed, including displacements, to review the short-term stability during the construction and the stability in view of long-term durability.

② The no-stress strain measurements should be used to investigate the external stress applied to the concrete and the spontaneous internal stress due to the internal temperature change, and the findings from the investigation need to be applied for quality control and the evaluation of the dam body's stability during construction.

(7) Analysis of pore water pressure measurement result from dam body and surrounding ground

① The pore water pressure measured at the core wall should be used to analyze the effective stress and the shearing strength and then applied to assess the stability of the dam body during the construction.

② For a concrete dam, the uplift pressure acting on the dam body should be used to assess the stability of the dam body.

6.3.11 Measurement Management Standard

(1) Since the criteria for monitoring management are determined by the type and size of dams, the

behavior of the foundation and abutment, geological conditions, construction materials, and construction methods, the reference values for the criteria are difficult to be clearly prescribed. Therefore, the criteria for each measured parameters should be determined by considering these factors. In general, it is considered to be reasonable to determine the criteria through a comprehensive review of the laboratory test results, theoretical and numerical analysis, initial construction performance, and the monitoring data from other dams under similar conditions.

(2) The pore water pressure distribution and the earth pressure measurements in the dam body should be used to regulate the embankment construction rate for the dam by adjusting the construction speed, embankment fill height, and the water content of embankment materials.

(3) The criterion for each monitoring parameter may be determined as absolute values or trend lines, and may be changed or adjusted depending on site conditions and circumstances with the approval of the relevant expert or authorities and institutions.

6.3.12 Report of Measurement Result

Must conform to 1.3.12.

7. Levee (Embankment) Construction

7.1 General

7.1.1 Scope of Application

(1) The purpose of monitoring management presented in this chapter is for safety and quality control during the levee construction.

(2) Monitoring management for any purpose other than the one described in (1) above is planned separately.

7.2 Materials

7.2.1 Types of Measurement Instrument

(1) The measurement error of the monitoring instrument used to measure the deformation of the levee should be within ± 1.0 mm.

(2) The measurement error of the monitoring instrument used to measure the settlement of the levee should be within ± 1.0 mm.

(3) The measurement range of the monitoring instrument used to measure the horizontal displacement of the river bank should be at least 100 mm, and the measurement error should be within ± 0.01 mm.

(4) The measurement range of pore water pressure should be determined by considering the pore

water pressure range from the design. In principle, the maximum measurable pore water pressure of the instrument should exceed 1 MPa.

7.2.2 Measurement Data Acquisition System

(1) For levee structure,, the monitoring plan should be include the monitoring during construction, the monitoring during the maintenance. For the monitoring, an automated measurement system should in principle be used to collect, process, and analyze the monitoring data.

(2) An automated monitoring data acquisition system should be able to transmit the measurement data obtained from the monitoring instrument to the computers in a remote monitoring room for storage and analysis of the monitoringdata.. The automated monitoring data acquisition system should in principle allow manual operation when necessary.

(3) When an automated monitoring data acquisition system is used, a power supplying device should be installed for the stable acquisition, storage, and transmission of monitoring. In addition, accessories including a voltage stabilizer, a dehumidifier, a thermostat, and a lightning protection device, should be equipped, and if necessary, a vibration-proof devices should be prepared to avoid the effect of vibration.

7.3 Construction

7.3.1 Installation of Measurement Instrument

(1) Appropriate monitoring instruments should be selected and purchased suitable for the construction site conditions considering the purposes of their utilization. The specifications of various instruments should be submitted to and approved by the owner/client before they are purchased and installed.

(2) The cable should be appropriately installed at the levee surface with sufficient slack to avoid cable breakage or damage against the levee settlement. Information about the type of monitoring instrument, serial number, and cable type should be indicated at the cable end to avoid confusion in cable selection.

(3) The engineer in charge of monitoring should install the monitoring instruments accurately following the procedures specified in the manuals provided by the manufacturers.

7.3.2 Correction of Measurement Instrument

(1) The normal operation of a monitoring instrument should be tested before and immediately after the installation. If necessary, the monitoring instrument should be calibrated.

(2) If the measurement value is changed unusually during the monitoring, the monitoring instrument should be checked. If necessary, the monitoring instrument should be calibrated.

7.3.3 Protection of Measurement Instrument

(1) The guiding lines connecting the monitoring instruments and the circuit link lines should be reinforced using steel wires, if they are buried in the foundation underneath the levee or in the levee. The lines and monitoring instruments should be reinforced against tension, external forces, impacts, and lightening, water-proofed, corrosion-proofed, and insulated.

(2) The engineer in charge of monitoring should review the installation instructions for each instrument to understand the general problems that may occur during installation, and establish protective measures for the monitoring instruments.

7.3.4 Installation of Data Transmission Cable

(1) The monitoring instrument cable should be a cable exclusively for the monitoring instrument. A single cable without connection from the laying point to the monitoring room should be used.

(2) The ends of the cable should be water-proofed to prevent the infiltration of water from monitoring to maintenance.

7.3.5 Inspection and Testing According to Measurement System Installation

(1) The monitoring instruments and the circuit link lines buried in the levee or other structures should be tested immediately after their installation. Back fill may proceeded only after their normal operation is verified by the test.

7.3.6 Management of Measurement Instrument

(1) To preserve the performance and secure the reliability of the monitoring results, the monitoring instrument should be managed following the methods and procedures provided by the manufacturers.

(2) A reliability of the monitoring instruments should be evaluated on a regular basis. The reliability evaluation should comprehensively consider the judgment on the changes with the passage of time, the judgment based on electrical examination, and the judgment based on the monitoring results including the levee behavior.

7.3.7 Execution of a Monitoring Program

(1) Monitoring should be performed and managed by a dedicated team.

(2) The person in charge of monitoring should be a construction engineer who understands the characteristics of the monitoring instruments and the behavior of the levee and foundation ground.

(3) Monitoring should be performed at least three times on the same day by using the monitoring instruments, and the average of the measurement values should be used for final results.

7.3.8 Monitoring Frequency

(1) The monitoring period during the construction is divided into the following four stages, and the monitoring frequency is as shown in Table 7.3-1. If the monitoring frequency has to be changed according to the measurement result, site conditions, and ground conditions, the validity of the change should be secured through an analysis of the measurement data, and the approval of the superintendent should be acquired before the change.

① Stage 1: One month after the installation of the monitoring instrument

② Stage 2: From one month after the installation of the monitoring instrument to the completion of levee construction

③ Stage 3: In the event of anomalies in the measurement values, until the safety is verified

④ Stage 4: One week after a flood or an earthquake

Table 7.3-1 Measurement frequency during river bank construction.

Measurement	Stage 1	Stage 2	Stage 3	Stage 4
Pore water pressure Groundwater level Foundation settlement	Daily	Once every 3 days	Daily	Daily
Horizontal displacement Slope surface displacement	Daily	Daily	Daily	Daily
Levee crown settlement	Daily	Daily	Daily	Daily
Automated measurement recording and computer control facility	Daily	Daily	Daily	Daily

(2) Since the measurements from the different instruments should be mutually compared and analyzed, the measurements should be performed in the same period. The measurements with a higher frequency should be processed separately.

7.3.9 Summary and Analysis of Measurement Result

(1) The project title, site location, name of levee, measurement location, monitoring parameters, monitoring locations, monitoring date and time, and name of monitoring engineer should be written on all the monitoring result data sheets.

(2) The monitoring results should be summarized for each of the measurement items in the predetermined format and must include the measurement date, number of days elapsed, current status of construction, initial values, measurement values obtained at the current monitoring, and changes in the measurement values. Plots for analyzing the monitoring data should be prepared as plots showing the change of each monitoring item over time at each position and the

distribution of the measurement values of each item in the levee structure, so that the results may be used to the construction and safety management.

(3) The monitoring result should be analyzed by a construction engineer who understands the levee and foundation ground behavior and has extensive experience in levee construction.

(4) The monitoring results should be analyzed with reference to the design drawings, the numerical analysis results at the construction site or at a similar construction site, the empirical values, other monitoring results, and the ground conditions of the construction site. The meonitoring management reference values are established by considering the absolute change and the rate of change of the monitoring values, and the stability is evaluated using these reference values.

(5) When an event influencibg the levee stability occurs, including abnormal floods and earthquakes, monitoring and analysis should be performed immediately to determine the normal conditions of the levee and other related structures. If there is a problem, a permanent countermeasure should be prepared.

(6) After the completion of the monitoring, the monitoring result should be summarized and submitted to the superintendent for verification to carry out the subsequent works.

7.3.10 Criteria for Monitoring Management

(1) Since the criteria for monitoring management are determined by the levee size, the behavior of both levee and foundation ground, geological conditions, construction materials, and construction methods, the reference values are difficult to clearly present. The criteria for monitoring management for each monitoring item should be determined by considering these factors. Generally, a reasonable method is to determine criteria of management through a comprehensive review of the laboratory test results, theoretical analysis, numerical analysis, initial construction results, and the levee monitoring results under similar conditions.

(2) The pore water pressure distribution on the levee should be used to regulate the mounding rate during the levee construction by adjusting the construction rate, mounding height, and the water content of construction materials.

(3) The criteria of monitoring management for individual measurement items may be determined as absolute values or trend lines, and may be changed or adjusted with the approval of the relevant expert or relevant authorities and institutions depending on the site conditions and circumstances.

7.3.11 Report of Measurement Result

Must conform to 1.3.12.

8. Port and Harbor Construction

8.1 General

8.1.1 Scope of Application

(1) This criteria for monitoring management is for safety and quality control during the port and harbor construction.

(2) Monitoring management for any purpose other than the one described in (1) above is planned separately.

8.2 Materials

8.2.1 Types of Measurement Instrument

(1) The measurement error of the monitoring instrument used to measure the deformation should be within ± 1.0 mm.

(2) The measurement error of the monitoring instrument used to measure the settlement should be within ± 1.0 mm.

(3) The measurement range for the measurement of the concrete strain should exceed 3,000με, and the detection minimum limit should be equal to or less than 0.1με.

8.2.2 Monitoring Data Acquisition System

(1) An automated monitoring data acquisition system should be able to transmit the monitoring data obtained from the monitoring instrument to the computers in a remote monitoring room for storage and analysis of the monitoring data. The automated monitoring data acquisition system should in principle allow manual operation when necessary.

(2) An automated monitoring data acquisition system should be able to remotely control the monitoring instruments at different positions to change the measurement frequency.

8.3 Construction

8.3.1 Installation of Measurement Instrument

(1) The monitoring instruments should be installed at the port and harbor structures and the adjacent surrounding grounds to accurately measure the behavior at those monitoring locations.

(2) The monitoring instruments needed for the monitoring of port and harbor structures should in principle be installed at the time of constructing the harbor structures.

(3) The monitoring instruments needed for the measurement of the surrounding ground adjacent to the port and harbor structures should in principle be installed before the construction of the port

and harbor structures.

(4) The engineer in charge of monitoring should install the monitoring instruments accurately following the procedures specified in the manuals provided by the manufacturers.

8.3.2 Correction of Measurement Instrument

(1) The normal operation of a monitoring instrument should be tested before and immediately after the installation. If necessary, the monitoring instrument should be calibrated.

(2) If the measurement value is changed unusually during the monitoring, the monitoring instrument should be checked. If necessary, the monitoring instrument should be calibrated.

8.3.3 Protection of Measurement Instrument

(1) The cables connecting monitoring instruments and data acquisition devices should be buried in the rock layer, soil layer or concrete. Even if they are exposed, the cables should be reinforced against tension, external forces, impacts, and lightning, water-proofed, corrosion-proofed, and insulated.

8.3.4 Installation of Data Transmission Cable

(1) The monitoring instrument cable should be a cable exclusively for the monitoring instrument. A single cable without connection from the laying point to the monitoring room should be used.

(2) The cable should be installed with a cable protection measure to avoid breakage of or damage to the cable due to the ground settlement. Information about the type of monitoring instrument, serial number, and cable type should be indicated at the cable end to avoid confusion in cable selection.

(3) The ends of the cable should be water-proofed to prevent the infiltration of water, from monitoring to maintenance.

8.3.5 Inspection and Testing According to Measurement System Installation

For the monitoring instruments installed in the inside or on the surface of the port and harbor structures and on the surrounding ground, monitoring should be performed immediately after the instrument installation. The remaining construction should be carried out only after the normal operation is verified.

8.3.6 Management of Measurement Instrument

(1) To preserve the performance and secure the reliability of the monitoring results, the monitoring instrument should be managed following the methods and procedures provided by the manufacturers.

(2) A reliability of the monitoring instruments should be evaluated on a regular basis. The reliability

evaluation should comprehensively consider the judgment on the changes with the passage of time, the judgment based on electrical examination, and the judgment based on the monitoring result including the behavior of port and harbor structures.

8.3.7 Execution of a Monitoring Program

(1) Monitoring should be performed and managed by a dedicated team.

(2) The person in charge of monitoring should be a construction engineer who understands the characteristics of the measurement instruments and the behavior of the port and harbor structures and the surrounding ground.

(3) Monitoring should be performed at least three times on the same day using the measurement instruments, and the average of the measurement values should be used for final results.

8.3.8 Monitoring Frequency

(1) The monitoring period during the construction is divided into the following five stages, and the monitoring frequency is shown in Tables 8.3-1 and 8.3-2.

① Harbor Structures

a. Stage 1: Construction of port and harbor structures

b. Stage 2: Placement of port and harbor structures

c. Stage 3: Back filling of port and harbor structures

d. Stage 4: Routine monitoring (Routine monitoring with no abnormality in Stage 3)

e. Stage 5: Emergency monitoring (In the presence of abnormal signs in the port and harbor structures)

Table 8.3-1 Measurement frequency in each stage of harbor structure construction.

Measurement	Manufacturing of harbor structures	Placing of harbor structures	Back filling works for harbor structures	Routine measurement	Emergency measurement
Harbor structure settlement Harbor structure horizontal deformation and inclination	-	Once every 10 min	Once every 30 min	Once per day	Once every 10 min
Rebar stressmeter Concrete stress Earth pressure Reaction force	Once/hour	Once every 10 min	Once every 30 min	Once per day	Once every 10 min

② Surrounding Ground

a. Stage 1: Placement of riprap mound

b. Stage 2: Placement of port and harbor structures

c. Stage 3: Back filling of port and harbor structures

d. Stage 4: Routine monitoring (Routine monitoring with no abnormality in Stage 3)

e. Stage 5: Emergency monitoring (In the presence of abnormal signs in the surrounding ground)

Table 8.3-2 Measurement frequency at surrounding ground.

Measurement	Placing of riprap mound	Placing of harbor structures	Back filling works for harbor structures	Routine measurement	Emergency measurement
Land-side ground surface settlement Land-side differential settlement Land-side underground settlement	Once every 30 min	Once every 10 min	Once every 30 min	Once per day	Once every 10 min
Harbor structure bottom settlement Harbor structure bottom differential settlement Riprap mound settlement	Once every 30 min	Once every 10 min	Once every 30 min	Once per day	Once every 10 min
Sea-slide underground displacement	Once every 30 min	Once every 10 min	Once every 30 min	Once per day	Once every 10 min
Tide gauge	Once every 30 min	Once every 10 min	Once every 30 min	Once per hour	Once every 10 min

(2) Different monitoring frequencies should be applied to the caisson area and the surrounding ground area.

(3) If the monitoring frequency has to be changed according to the monitoring result, site conditions, and ground conditions, the validity of the change should be secured through an analysis of the monitoring data, and the approval of the construction supervisor should be acquired before the change.

(4) Since the measurements from the different instruments should be mutually compared and analyzed, the measurements should be performed in the same period. The measurements with a higher frequency should be processed separately.

8.3.9 Summary and Analysis of Measurement Result

(1) The monitoring result should be analyzed by a construction engineer who understands behavior of the port and harbor structures and the surrounding ground and has extensive experience in port and harbor construction.

(2) The project title, position, name of structure, measurement locations, monitoring parameters, monitoring locations, meonitoring date and time, and name of the monitoring engineer should be

written on all the monitoring result data sheets.

(3) The monitoring results should be summarized for each of the measurement items in the predetermined format and must include the measurement date, number of days elapsed, current status of construction works, initial values, measurement values obtained at the current measurement, and changes of the measurement values. Plots for analyzing the monitoring data should be prepared as plots showing the change of each monitoring item over time at each position and the distribution of the measurement values of each item, so that the results may be applied to the construction and safety management.

(4) If the monitoring results shows that the port and harbor structures have a problem, an appropriate emergency action should be taken, and the causes should be investigated to prepare a permanent solution.

(5) After the completion of monitoring, the monitoring result should be summarized and submitted to the superintendent for verification to carry out the subsequent works.

(6) Analysis of port and harbor structure monitoring results

① The stress and reaction force (earth pressure) monitoring results from the port and harbor structures should be used to review the caisson stress distribution in order to verify the appropriateness of the design and the structural stability and to investigate the reaction force during the placement of the structures as well as the load blocks.

② The deformation of the port and harbor structures should be analyzed based on the change over time, the range of change, and the presence of differential settlement to determine the basic stability. The settlement and the horizontal displacement (slope) should be measured simultaneously to analyze the behavior of the harbor structure depending on the construction works.

(7) Analysis of monitoring results from surrounding ground of port and harbor structures

① The underground settlement and underground horizontal displacement monitoring results from the surrounding ground should be analyzed together with the deformation and stress monitoring results of the port and harbor structures to review the possibility of abnormal behavior by back filling and mounding work.

8.3.10 Criteria for Monitoring Management

(1) The monitoring result should be analyzed with reference to the design drawings, the numerical analysis results at the construction site or at a similar construction site, the empirical values, other monitoring results, and the ground conditions of the construction site. The monitoring management reference values are established by considering the absolute change and the rate of change of the measurement values, and the stability is evaluated using these reference values.

(2) Since criteria for monitoring management are determined by the type and size of port and harbor

structures, the surrounding ground, geological conditions, tide level, and construction methods, the reference values are difficult to clearly present. The criteria for monitoring management for each monitoring item should be determined by considering these factors. In general, a reasonable approach is to determine criteria for monitoring management through a comprehensive review of the laboratory test results, theoretical analysis, numerical analysis, initial construction results, and the port and harbor structure monitoring results under similar conditions.

(3) The monitoring results of settlement and horizontal displacement of the port and harbor structures and the surrounding ground should be used to regulate the port and harbor construction by adjusting the construction rate, back filling rate, and mounding height.

(4) The criteria for monitoring management for individual measurement items may be determined as absolute values, trend lines or displacement velocities, and may be changed or adjusted under the approval of the relevant expert or relevant authorities and institutions depending on the site conditions and circumstances.

8.3.11 Report of Measurement Result

Must conform to 1.3.12.

9. Architectural Construction

9.1 General

9.1.1 Scope of Application

(1) The purpose of this chapter is to support safety management in architectural construction.

(2) The purpose described in (1) above also includes the installation of monitoring instruments and the monitoring during the construction processes for the monitoring of buildings behavior after their architectural construction.

(3) Monitoring is performed during the architectural construction to ensure the safety of the structures by monitoring the slope, displacement, load, settlement, and others. The following monitorings are specified:

① Monitoring of deflection of buildings where deflection management is needed for long-span structures

② Monitoring of column shortening of high-rise buildings

③ Monitoring of cracks in the presence of cracks that are suspected to harm the structural safety

④ Monitoring of surrounding buildings when damage occurs or there is concern over damage to surrounding buildings due to the effects of excavation works and vibration

⑤ Monitoring of stress in very important structural members where a large stress is generated

⑥ Monitoring of strain of key structural members of very important buildings

(4) In addition to the cases specified in (3) above, monitoring management is carried out by preparing a separate monitoring plan where safety management during construction works is needed.

9.2 Materials

9.2.1 Types of Measurement Instrument

(1) The measurement error of the monitoring instrument used to measure the settlement should be within ± 1.0 mm.

(2) Monitoring of inclination: The monitoring instrument used to measure inclination should in principle be one that may predict the three(X, Y, and Z)-axis movement of a building to measure the displacement of the building simultaneously in the three axes.

(3) Monitoring of strain: If an electric resistance type monitoring instrument is used for the measurement of local displacement of a target member. For monitoring of wide ranges of strains of a structure member, optical fiber gauges, long gauges, and laser gauges are used.

(4) Monitoring of crack: A crack measurement method and an instrument that are economical and appropriate for the purpose should be selected considering the precision and purposes of crack monitoring.

(5) The monitoring instruments should not be influenced by external conditions, including the temperature variation, corrosion, humidity, vibration, and electromagnetic field.

9.3 Construction

9.3.1 Installation of Measurement Instrument

(1) Monitoring of inclination

① The monitoring instrument should be installed at a location that best represents the inclination of the building.

② A tilt plate should be attached to a firm ground surface, which is not deformed by the construction works, temperature, humidity, and other factors.

(2) Monitoring of stress

① The instruments for monitoring stress should be installed at the key structural members to investigate the excessive stress on the structure.

② Load sensors are installed during the construction process of the target structure.

(3) Monitoring of column shortening

① The monitoring instrument should be installed at the key columns and core walls of the target building.

② The columns, at which the monitoring instruments are installed, should be influenced by only physical shortening; therefore, other factorspossible of material defects such as cracks and cavities should not exist.

③ The monitoring instrument should be installed at the center of the columns or walls in parallel with the axial direction.

9.3.2 Correction of Measurement Instrument

(1) The normal operation of a monitoring instrument should be tested before and immediately after installation. If necessary, the monitoring instrument should be calibrated.

(2) If the monitoring value is changed unusually during the measurement, the measurement instrument should be checked. If necessary, the monitoring instrument should be calibrated.

9.3.3 Protection of Measurement Instrument

The installed monitoring instrument should be protected from the construction works and other effects, to avoid damages.

9.3.4 Installation of Data Transmission Cable

Must conform to 1.3.4.

9.3.5 Inspection and Testing According to Measurement System Installation

Must conform to 1.3.5.

9.3.6 Maintenance of Monitoring Instruments

(1) To preserve the performance and secure the reliability of the monitoring results, the monitoring instruments should be managed according to the methods and procedures provided by the manufacturers.

(2) In the cases where a monitoring instrument has been damaged, an additional monitoring instrument should be installed at an adjacent position to continue the monitoring of performance.

(3) The person who installs the monitoring instruments should take sufficient protective measures to prevent the loss of the instruments until the purposes of the monitoring have been fulfilled.

9.3.7 Execution of Monitoring Program

(1) Monitoring should be performed and managed by a dedicated team.

(2) The person in charge of monitoring should be a construction engineer who understands the characteristics of the monitoring instruments and the behavior of the target structure.

(3) If long-term safety management is needed due to general conditions, monitoring instruments for

long-term safety management should be installed. All of the related details should be documented and provided to the owner/client at the completion of construction so that the monitoring may be carried out during the operation of the facilities on a regular basis.

(4) If an error is included in the monitoring data or the reliability of the data may not be recognized due to the damage or malfunctioning of a monitoring instrument during the monitoring, the initial values should be determined again. The correlation with previous monitoring should be determined in consultation with relevant experts and the construction supervisor.

(5) Displacement should be measured as absolute displacement or relative displacement depending on the monitoring purpose.

(6) In the presence of routine cracking and extending factors due to temperature variation, groundwater level variation, and loading, relevant monitoring such as temperature and groundwater level should be performed simultaneously, or the necessary data should be acquired.

9.3.8 Monitoring Frequency

(1) The monitoring frequency should be determined by considering the frequency of the load variation and the destruction and collapse modes of the target structure. The monitoring data should have a resolution that allows an engineer to sufficiently understand the behavior of the building.

(2) The monitoring frequency may be changed when necessary considering the site conditions and the ground conditions after the approval of the superintendent has been obtained.

(3) Monitoring of settlement

① In the early stage of the construction works, settlement should be monitored 2 to 3 times per week. After the monitoring data are stabilized, the frequency may be gradually adjusted.

② The monitoring of settlement should be performed each time a new layer is added on top of the structure.

(4) Monitoring of strain

① Monitoring of strain is performed through regular and provisional monitoring.

② The frequency of regular monitoring is determined in consultation with the superintendent, designers, or other relevant persons.

③ Provisional monitoring is determined at the discretion of the manager when there is concern over a sudden application of load due to wind or snow.

(5) Monitoring of column shortening should be performed each time a new layer is added on top of the structure, at a minimum.

9.3.9 Monitoring Period

(1) The monitoring period with a settlement gauge is from the installation of the monitoring instrument to the confirmation of the convergence of the settlements. The convergence of the settlements is

determined by considering the settlement monitored over a certain period with reference to the absolute settlement or the settlement relative to the total cumulative settlement.

(2) The monitoring period with an inclinometer is from the installation of the monitoring instrument to the confirmation of the convergence of the displacements. The completion of the inclination monitoring should be determined by considering the convergence of the monitoring results obtained by an underground inclinometer, a soil retaining wall inclinometer, and a water level meter.

(3) The monitoring period for strain measurement is from the installation of the monitoring instrument to the completion of the construction.

9.3.10 Summary and Analysis of Measurement Result

(1) Monitoring of settlement

① Before the measurement, the management values should be determined according to the structure type, foundation type, importance of structure, and predicted settlement, and the approval of the construction supervisor should be obtained with regard to the management values.

② If the absolute settlement or the relative settlement exceeds the management values, the target values should be re-established or appropriate actions should be taken, including the reinforcement of the ground, in consultation with the experts.

(2) Monitoring of inclination

① When the monitoring instrument has to be temporarily removed due to the construction works, including the finishing, the final monitoring should be performed with the approval of the supertentendent. The initial values should be determined after re-installation, referring to the previous data.

② In the monitoring of the inclination at the existing structures around the construction site, the analysis should be performed after thoroughly investigating the state of the existing structures.

③ A comprehensive data analysis should be carried out by reviewing the monitoring data obtained using the underground inclinometer, the earth retaining wall inclinometer, and the water level meter.

(3) Monitoring of displacement

① In the monitoring of displacement, the effects of temperature variation, creep, and other external environmental factors should be taken into consideration. To this end, additional analyses may be performed by using the relevant monitoring results.

② The strength and elastic modulus of the target structures should be obtained by performing experiments or from reliable data. The analysis should be performed on the basis of these data.

③ The deflection should be calculated through analysis before the installation of the monitoring instrument, and then the monitoring results should be analyzed.

(4) Monitoring of strain

① The strength and elastic modulus of the target structures should be obtained by performing experiments or from reliable data. The analysis should be performed on the basis of the strain.

② The stress should be monitored through the stress-strain curve. If the stress exceeds the yield strength, the construction should be discontinued immediately, and countermeasures prepared.

(5) Monitoring of cracks

① Before the monitoring of cracks, an analysis of the cracks to be measured should be performed with respect to the causes and shapes of the cracks, as well as the stress status.

② In the monitoring of the cracks, the variation of both the crack width and length should be investigated for analysis.

③ Since cracks are developed in different patterns depending on the toughness and thickness of the materials, the properties of the materials should be considered in the analysis.

④ Actions against cracks should be taken after considering the importance of the structures or the structural members, the properties of the materials, the pattern of cracks, and the trend of cracking.

(6) Monitoring of column shortening

① The monitoring results are obtained as average strain values. After the monitoring, creep should also be considered in the analysis.

② The predicted shortening and the measured shortening should be compared on a regular basis for re-analysis or re-correction.

③ Re-analysis or re-correction should be determined in consultation with the superintendent before the construction works. Re-analysis or re-correction should in principle be performed every 10 to 20 layers.

9.3.11 Criteria for Monitoring Management

(1) The criteria for monitoring management should be determined in consultation with the superintendent at the construction site by comprehensively considering not only the building factors such as the structure type, status, and importance of the building; the member factors such as the material properties, structural mechanical conditions, and destruction mode of the target structural members; but also the regional and environmental conditions.

(2) The criteria for monitoring management must be established before the beginning of monitoring. If

there is a justifiable reason, the criteria for monitoring management may be changed or adjusted during the performance of monitoring with the approval of the relevant expert or relevant authorities and institutions depending on the site conditions and circumstances.

9.3.12 Report of Measurement Result

Must conform to 1.3.12.

10. Underground Excavation

10.1 General

10.1.1 Scope of Application

(1) The purpose of the monitoring management in this chapter is for safety management during excavation works.

(2) Details that are not specified according to the purpose described in (1) above should conform to the Common Criteria Section. Details that are not specified even in the Common Criteria Section should conform to the relevant design standards and standard specifications.

10.2 Materials

10.2.1 Types of Measurement Instrument

(1) Underground horizontal displacement meter (inclinometer): An underground inclinometer is used when ground displacement is expected due to the soft ground to be excavated or in the presence of an important structure within the range affected by the excavation works.

(2) Water level meter: A water level meter is used when a change in the groundwater level is expected due to the excavation works, or if an important structure exists within the range affected by the excavation works.

(3) Strain gauge: A strain gauge is used to the supports of stress, including the struts, H-piles, middle piles, and wale, which are the supports for the retaining structures involved in excavation works, as well as H-beams applied to road decking paneled areas.

(4) Surface settlement gauge: A surface settlement gauge is used when the excavation depth is significant and ground settlement due to groundwater leakage is expected, or when backfill ground settlement is expected due to the displacement of the wall because the retaining wall is soft.

(5) Underground settlement gauge (extensometer): An underground settlement gauge is used when an important underground structure is buried near to the soft ground excavation work site.

(6) Tiltmeter: A tiltmeter is used to monitor the inclination change of a building or a structure due to

differential settlement within the range influenced by the ground displacement caused by excavation works.

(7) Crack meter: A crack meter is used to monitor the cracks generated on a building or a structure within the range influenced by the ground displacement caused by excavation works.

10.2.2 Measurement Data Acquisition System

(1) A monitoring data acquisition system should be constructed after considering the convenience of monitoring, monitoring frequency, monitoring method, instrument compatibility and economic feasibility.

(2) Monitoring instrument operation methods can be classified into manual monitoring instrument operation and automated monitoring instrument operation. An appropriate monitoring instrument operation method should be selected after considering the characteristics of the collapse and sliding progress, the importance of the monitoring target facility, effect of damage occurrence, economic feasibility, and monitoring frequency.

10.3 Construction

10.3.1 Installation of Measurement Instrument

(1) The monitoringmeasurement instruments installed outside the excavation work site should be installed before the excavation works so that the initial values may be completely measured before the monitoring locationmeasurement positions are affected influenced by the excavation works. The monitoringmeasurement instruments installed inside the excavation work site should be installed immediately after the excavation works or the installation of the temporary members in order to promptly measure the initial values.

(2) Underground horizontal displacement meter (inclinometer)

① The inclinometer should be installed at a position about 0.5 m away from an H-pile or wall of an important structure in the backfillback face to secure a sufficient working space.

② The drilling diameter for the installation of an inclinometer should be large enough to allow grouting after the insertion of the inclinometer tube.

③ If a grouting pipe is inserted in addition to an inclinometer tube, the diameter should be large enough to allow the insertion of both. If the insertion of a grouting pipe is not necessary, the diameter should be large enough to allow the passage of filling materials for grouting through the external space of the inclinometer tube.

④ In a layer where there is the risk of collapse of a retaining wall due to drilling, the retaining wall should be protected using a casing.

⑤ The drilling depth should be at least 1.5 m into a solid layer where the displacement of

the ground is not expected to serve as a reference for the horizontal displacement measurement.

⑥ The joint of the inclinometer tube should be sealed after riveting with silicon or tape to block the filling materials for grouting.

⑦ In the monitoringmeasurement with an inclinometer, sufficient grouting should be performed to prevent the vibration of the inclinometer, and an appropriate curing period should be provided to increase the reliability of the initial values.

⑧ If the earth retaining wall is a diaphragm wall, an underground inclinometer should be installed inside the wall to directly measure the wall displacement resulting from the excavation works.

(3) Water level meter

① The monitoringmeasurement positions locations and the drilling instrument installation should be performed according to the details of the underground horizontal displacement meter.

② A water permeable layer should be formed by filling the bottom of the hole in a thickness of about 0.5 m with sand and gravel having a proper particle size distribution. To prevent the formation of cavities, the size of the particles in the water permeable layer should not be excessively large.

③ The earth to fill the overbreak should have a similar water permeability to the original ground.

④ When a water or sewage pipe near the monitoringmeasurement instrument is broken, the lowering of the groundwater level by the excavation works may not be sufficiently monitoredeasured. For this reason, the separation distance between the monitoringmeasurement instrument and the water pipe or sewage as well as the pipe size should be documented to understand the effect.

⑤ The flow net rearranged by the excavation works should be measured to predict the affected distance and the possibility of damage by linearly arranging the water level meters at a consistent interval.

(4) Strain gauge

① Strain gauges of the sizes and types appropriate for the purposes should be selected and installed (electric resistance type, V.W type, buried type, and surface attached type).

② The strain gauges should be installed in parallel with the measurement direction and firmly attached to a member as one body.

③ Since the gauges installed on a steel material may lose their functions due to high voltage, the wires should not be in direct contact with the steel material.

④ If the cable should be extended from the installation position to the measurement locationposition, the connection should be accurate, complete, and waterproofed to

prevent damage to the connecting parts.

(5) Surface settlement gauge

① The surface settlement gauges should both be installed in parallel with the earth retaining wall and in a perpendicular direction to the earth retaining wall.

② The measurement reference point should be fixed at an unmovable position. If a fixed position is difficult to obtain, a steel bar may be buried to establish a fixed position.

(6) Underground extensometer

① Holes should be drilled after determining the drilling depth according to the installation positions of an important structure.

② Sensors should be placed on the outside of the casing according to the desired number of measurement positions, and then inserted into the holes.

③ Grouting should be performed for the overbreak in the holes.

④ The casing should be inserted into the part where the borehole is not self-standing. The casing should be removed after the installation of the monitoringmeasurement instrument is finished.

⑤ The initial values should be measured after the curing of the grouting for the drilled holes.

(7) Tiltmeter

① Axis 1 of Axis 1 to Axis 3 of a tiltmeter plate should be directed toward the construction site, and the level should be maintained.

(8) Crack meter

① Monitoringeasurement of cracks of a building or a structure within the range influencedaffected by the excavation works should be performed before the excavation works to secure the initial values, which should be confirmed by the owner of the building or structure.

② In addition to the crack monitoringmeasurement performed using the monitoringmeasurement instruments, photos or videos should be stored as evidence.

10.3.2 Correction of Measurement Instrument

(1) The normal operation of a monitoring instrument should be tested before and immediately after the installation. If necessary, the monitoring instrument should be calibrated.

10.3.3 Protection of Measurement Instrument

(1) A monitoring instrument that is partly exposed should be protected using an appropriate protective device to avoid damage caused by construction equipment or by people. A signboard indicating the presence of the monitoring instrument should be installed at a

location that is easily viewable.

(2) The underground horizontal displacement meter should be capped at the top of the measurement tube after grouting so that impurities such as soil or rock debris may not be inserted.

(3) If runoff water or rainwater may flow into a water level meter and an underground extensometer from the ground's surface above the top of the measurement tube, concrete or mortar should be placed around the tube, and the top of the excavation holes should be completely sealed to prevent the inflow of surface water.

(4) A surface settlement meter should be covered with a protective cap after the curing of the concrete on the measurement mark foundation.

10.3.4 Installation of Data Transmission Cable

(1) The cable for the transmission of monitoring data should have an appropriate format for continuous monitoring. An installation plan should be prepared with regard to the cable routing, communication protocol, cable connection and access.

(2) The monitoring instrument cable should be a cable that is exclusively for the monitoring instrument. A single cable with no connection point from the laying point to the monitoring room should be used.

(3) The cables for all monitoring instruments should be protected by installing a pipe for monitoring.

10.3.5 Inspection and Testing According to Measurement System Installation

(1) Following the installation works for the monitoring system, the correction and tests should be performed, and then a test-run should be performed as follows.

① The person in charge of the monitoring instrument installation has the duty for the primary test-run of the instruments under load-free conditions. After the completion of the test-run, the person in charge of the installation of the monitoring instrument should prepare a test-run result report and submit it to the superintendent.

② A comprehensive test-run, a test-run under load, should be performed to test all the functions, including the comprehensive test-run with other facilities linked with the current instrument.

10.3.6 Management of Measurement Instrument

(1) The monitoring instrument should be managed according to the methods and procedures provided by the manufacturers to preserve the performance and secure the reliability of the monitoring results.

(2) A guideline label and a name tag should be attached to the monitoring instruments and the data acquisition systems.

10.3.7 Performance of Measurement

(1) Monitoring should be performed and managed by a dedicated team.

(2) The person in charge of monitoring should be an advanced construction engineer who understands the characteristics of the monitoring instruments and the behavior of the ground and temporary structures depending on the specific excavation works.

(3) Strain monitoring should be performed using the strain gauges for struts once both before and after the strut placement. Monitoring should be recorded after the screw-jack pressurization. Monitoring should be performed using the displacement meter for furring strips after the installation and then recorded after the screw-jack pressurization.

(4) Monitoring should be performed using the strain gauges for H-piles once after the placement of furring strips. The monitoring is performed once for struts after the screw-jack pressurization, and, for anchors, once during the tensioning and once after the completion of the tensioning.

(5) The monitoring of surface settlement should be performed at least three times repeatedly, and a verified value should be recorded.

(6) If the monitoring values from a tiltmeter are not stable and are slightly varied, the monitoring should be performed two or three times.

10.3.8 Monitoring Frequency

(1) Different monitoring frequencies should be determined for collapse-causing members and non-collapse-causing members.

(2) Real-time monitoring should be performed when an additional load is applied to a collapse-causing member. A normal monitoring frequency is applied to non-collapse-causing members.

10.3.9 Monitoring Period

(1) The monitoring period is from the installation of the monitoring instruments to the end of the backfill works following the completion of the underground structures.

(2) The monitoring period for the monitoring instruments for struts is from the installation of the monitoring instruments to the disassembly of the struts.

10.3.10 Summary and Analysis of Measurement Result

(1) The monitoring result data sheets should specify the layer configuration, installation and disassembly of supports, types of earth retaining walls, distance from adjacent structures, and the architectural type, aging, foundation type and depth of the adjacent structures.

(2) The monitoring results should be presented in plots showing the change over time, which should include the groundwater level, current variation of excavation depth, installation and disassembly of supports, and temperature.

(3) The monitoring results from underground inclinometers should be analyzed with the management criteria values depending on the excavation depth and the plots showing the change over time at each excavation depth.

10.3.11 Criteria for Monitoring Management

(1) Since criteria for monitoring management are determined by the behavior of the ground, the mechanical conditions of the temporary facilities and earth pressure, and the safety limits of adjacent structures, the reference values are difficult to clearly present. Therefore, the criteria for monitoring management should be determined by considering the site conditions.

(2) The management criteria values for stress gauges should be determined by performing structural analysis and an laboratory test considering the load conditions at the time of installing the monitoring instruments.

(3) When there are various displacement meters, crack meters, and water level meters, the measurement standards should be determined after verifying the initial values. Specific methods of establishing the initial values should be provided.

(4) The criteria for monitoring management for underground horizontal displacement meters may be determined by referring to the following values:

① The allowable internal inclination should be determined by considering the deformation of earth retaining walls according to the strength of the earth retaining walls, the characteristics of the excavated ground, excavation depth, supporting structures, and the countermeasures to groundwater.

② The easiest method of establishing the maximum allowable displacement is to refer to the strength of the earth retaining walls and the excavation depth (H). Generally, the maximum allowable displacement may be appropriately determined as follows:

a. Rigid earth retaining wall (concrete diaphragm wall thickness t≥60 cm): 0.002 H

b. Normal earth retaining wall (concrete diaphragm wall thickness t≒40 cm): 0.0025 H

c. Flexible earth retaining wall (earth retaining walls installed by using H-piles and retaining plates): 0.003 H

③ The maximum allowable displacement for the prevention of cracks on adjacent ground each day should be determined as follows:

a. Displacement (Ω) ≤ 2 mm (for 7 days): safe side

b. 2 mm < Ω ≤ 4 mm (for 7 days): cautions needed

c. 4 mm < Ω ≤ 10 mm (for 7 days): special management needed

d. 10 mm < Ω (for 7 days): urgent action needed

④ The abnormal displacement reference values for each day to inspect the slipperiness of rocks or the relaxation of ground anchorages are as follows.

a. Ω ≤ 1 mm (for 1 day): safe side

b. 1 mm < ≙ ≤ 2 mm (for 1 day): cautions needed

c. 2 mm < ≙ ≤ 4 mm (for 1 day): special management needed

d. 4 mm < ≙ (for 1 day): urgent action needed

⑤ The criteria for monitoring management may be inappropriate for the site conditions, or may include errors from the monitoring instruments. Therefore, the monitoring should be performed steadily, and corrected according to the site conditions at each excavation stage.

⑥ The wall deformation should be determined on the basis of the estimations in the design stage

a. F < 0.8: danger, where F = estimation in the design stage / actually measured deformation

b. 0.8≤ F < 1.2: cautions needed

c. 1.2 ≤ F: stable

(5) The criteria for monitoring management for water level meters may be determined by referring to the following details:

① The criteria for monitoring management should be determined at the construction site by considering the site conditions and excavation work circumstances, rather than in the design stage.

② In the event of a rapid lowering of the groundwater level, the excavation should be immediately stopped to verify any problems with the cutoff walls and the settlement of the back face ground. Excavation may be resumed if the groundwater level is recovered or if no problem is found.

(6) The criteria for monitoring management for tiltmeters are determined by referring to the limits of the individual displacement values affecting the structures and the damage limits of the structures depending on the types of the structural foundations.

10.3.12 Report of Monitoring Result

(1) The monitoring results should be summarized immediately after monitoring is performed. The data obtained at the construction site should be analyzed by considering the construction work conditions and the meteorological conditions, and visualized using plots. The analysis should be performed by interconnecting various monitoring results. If an anomaly is found through the comparison with the predicted values, the anomaly should be immediately reported to the Owner/Client and the superintendent.

(2) Other details should basically be determined according to 1.3.12.

11. Construction with Blasting and Vibration

11.1 General

11.1.1 Scope of Application

(1) The purpose of monitoring management in this chapter is for safety management during blasting performed for various construction works.

(2) Blasting monitoring management can be divided into test-blasting monitoring management performed at the beginning of blasting works, and continuous blasting monitoring management performed at safety targets located in the range affected by blasting during blasting works.

11.2 Materials

Not applicable.

11.3 Construction

11.3.1 Installation of Monitoring Instrument

(1) The person in charge of monitoring should install the monitoring instruments accurately and according to the procedures specified in the manuals provided by the manufacturers.

(2) Installation of blasting vibration monitoring instruments

① The methods of installation depending on the vibration acceleration are as follows:

a. The ground conditions should be examined, as the accuracy of the measurement values obtained from vibration gauges may be influenced by the conditions of the ground on which the gauges are installed, including sand, uncompacted soil, flower bed, and straw.

b. Vibration gauges should be installed as horizontally as possible for optimal performance.

c. The forward element of vibration gauges should be measured by installing the gauges to make the direction marked on the gauge the same as the direction of the blast source.

d. The installation or attachment of a vibration gauge is not necessary if the vibration acceleration is below 0.2 g.

e. If the vibration acceleration is between 0.2 g and 1.0 g, it is appropriate to bury an attached vibration gauge, which may be fixed using spikes. In addition, if the spikes of the gauge are not inserted into the ground, the gauge may be completely and uniformly covered with sand bags to apply a load so that the gauge may be moved along with the ground.

f. If the vibration acceleration is over 1.0 g, the gauge should be buried or tightly attached.

② The attachment or burial should be performed through the following methods:

a. The burial depth should not exceed three times the height of the monitoring instrument.

The monitoring instrument may be enveloped with a plastic bag before burial. The monitoring instrument may be piled on the ground using the spikes attached to the instrument, and the sides and top of the instrument may be firmly compacted with the soil.

b. If the ground is very hard or if the monitoring instrument should be installed on a concrete structure or a rock, the monitoring instrument should be fixed with a fixing plate as well as bolts and anchors. The instrument may be adhered to the rock surface or ground by using plaster, cement mortar, two-sided adhesive, epoxy resin, rubber clay, and clay lumps.

c. If the foundation of the structure is within ± 30 mm from the surface, the monitoring instrument may be attached to the foundation of the structure. However, this method should be employed only when it is difficult to apply other methods, including burial, spike fixing, and sand bag covering.

③ The following details should be observed during installation:

a. When fixing with spikes, turf should be removed to minimize the disturbance of the earth. Instruments with spikes should be solidly pressed into the ground.

b. If the spikes of the monitoring instrument are not inserted into the ground, the instrument may be covered with sand bags of a sufficient size. The sand bags should be loosely filled with sand to a weight between 50 and 120 N. The vertical cross-section should be as low and wide as possible to firmly contact with the ground. The sand bags should cover the monitoring instrument to apply a load on the instrument so that the behavior of the instrument may be synchronized with the ground.

(3) Installation of blast noise (blast pressure) monitoring instrument

① When there are buildings and automobiles located near to the monitoring locations, the microphones for measuring noise should be installed so as not to be influenced by the blast pressure. If the obstacles are unavoidable, the horizontal distance between the obstacles and the microphones for monitoring the noise should be longer than the height of the obstacles located above the microphones.

② If the microphones are installed too closely to a structure, the blast pressure may be amplified by the reflection on the building surface. Therefore, if possible, the monitoring instrument used to measure the noise should be installed at the corners to minimize the echo generated by the structure.

③ A windshield screen provided by the manufacturer of the monitoring instrument should be attached to reduce the effect of wind.

11.3.2 Correction of Monitoring Instrument

(1) The normal operation of a monitoring instrument should be tested before and immediately after

the installation. If necessary, the monitoring instrument should be calibrated.

(2) If the monitoring value is changed unusually during the monitoring, the monitoring instrument should be checked. If necessary, the monitoring instrument should be calibrated.

(3) Monitoring instruments for which one year has passed since their purchase or last calibration, or that have been frequently used, should be calibrated.

(4) Monitoring of blast vibration

① The ground vibration trigger level should be determined by considering the vibration speed predicted according to the monitoring purposes. While the trigger level may be determined according to the ground vibration or blast pressure, it is generally determined based on the vibration.

② The resolution of the waves to be recorded should allow the analyst to determine whether the measured wave is from the blast or not.

③ The vibration recording time should be determined by considering the speed of sound, the distance from the blast source, and the blast duration. In principle, the vibration recording time is determined as the time two seconds longer than the blast vibration duration, and one second is added for every 300 m from the blast source.

④ The maximum blast duration should be carefully determined to be longer than the blast duration in delayed blasting.

(5) Monitoring of blast noise (blast pressure)

① The surrounding background noise should be monitored in advance to minimize the malfunctioning due to noises, and the trigger level should be determined to be higher than the background noise.

② When only the blast noise should be monitored, the trigger level should be lowered sufficiently according to the blast pressure.

③ When only the blast noise is monitored, the monitoring duration should be longer than the blast duration. When both the ground vibration and the blast pressure are monitored, the ground vibration monitoring settings should be followed.

11.3.3 Maintenance of Monitoring Instrument

(1) To preserve the performance and secure the reliability of the monitoring results, the monitoring instrument should be managed according to the methods and procedures provided by the manufacturers.

(2) In manual monitoring, the factors that may cause vibration and noise should be excluded as much as possible.

(3) In automated monitoring, signboards announcing the performance of monitoring should be placed around the monitoring instrument, at positions that are not too close to the instrument.

11.3.4 Execution of Monitoring Program

(1) The person in charge of monitoring should be an advanced construction engineer who understands the characteristics of the monitoring instruments and the effects of blasting noise and vibration.

(2) The monitoring should be performed by a dedicated blast engineering company in order to accumulate objective data to verify the security of surrounding safety targets and to prepare for future civil complaints related to blasting works.

(3) The blast vibration and noise (blast pressure) should be monitored according to the monitoring methods for each monitoring item.

(4) The monitoring for test-blast should be performed according to the following details:

① Since the test-blast is performed to investigate the propagation characteristics of the ground to obtain the on-site vibration estimation equation for analyzing the area affected by the blast, the monitoring instruments should be placed linearly at a consistent interval in the direction of the key safety targets.

② To obtain the best attenuation relation, the monitoring line should be set in an area where the geological conditions are consistent to place the monitoring instruments.

③ The monitoring should in principle be performed simultaneously with respect to three elements: vertical element (V), longitudinal element (L), and transverse element (T).

④ The quantitative analysis of the test-blast results requires a statistically significant number of monitoring data. The number of times of blasting and the number of installed monitoring instruments should be determined to acquire at least 30 monitoring locations in order to increase the reliability.

⑤ The monitoring instrument should be firmly fixed on the ground or the structure that may show behavior synchronized with the ground motion. On a solid foundation, the monitoring instrument should be firmly installed using the spikes attached to the instrument.

⑥ The monitoring instrument should be installed such that the direction marked on the gauge is always the same as the direction of the blast source.

11.3.5 Monitoring Frequency

(1) For excavation by blasting, the vibration and noise should be monitored at each blasting.

(2) For excavation by machines, the vibration and noise should be monitored at a frequency of 2 to 3 times/day.

11.3.6 Summary and Analysis of Monitoring Result

(1) The monitoring result should be analyzed by a construction engineer who understands blasting noise and vibration and has extensive experience in blasting.

(2) The title of the construction project, location, date, construction company, and monitoring company should be recorded on the monitoring result data sheets.

(3) If the analysis of the monitoring result shows that the blast has various effects on the surrounding environment, appropriate actions should be taken and the causes should be identified before performing subsequent blasting works.

(4) After the completion of monitoring, the monitoring result should be summarized and submitted to the superintendent for verification to carry out the subsequent works.

(5) The analysis of the monitoring result should be performed in accordance with the following details:

① For a quantitative regression analysis, the test-blasting should in principle be performed in different patterns by varying the drilling and the explosive charge. If a single blast pattern is applied, the monitoring distance should be varied to acquire various scaled distances.

② Monitoring data obtained from at least 30 monitoring locations should be used in the analysis.

③ The statistical analysis of the monitoring data should be performed through a regression analysis method. The input data should be based on the peak particle velocity (PPV) of the individual elements.

④ The regression analysis should be performed on the basis of the square-root scaled distance and the cube-root scaled distance, and an estimation equation having a higher goodness-of-fit should be applied.

⑤ The confidence level of 95% should be applied to the blast vibration estimation equation obtained through the regression analysis.

⑥ If the correlation coefficient of the monitoring result estimation equation is less than 0.70, the test-blast should be performed again.

11.3.7 Criteria for Monitoring Management

(1) In the analysis and evaluation of blast vibration, numerical limits are needed as the basis of judgment. However, since the numerical limits are dependent on the materials, structural configurations, and foundations of the structures as well as the incident angle and frequency of vibration waves, clear legal regulatory standards have not yet been prepared in Korea. As a result, different criteria are flexibly regulated by Owners/Clients. Therefore, the experts should determine the appropriate allowable blast vibration values by referring to the blast vibration criteria that are currently applied in Korea and their background.

(2) The blast vibration criteria should be suggested according to the current status of the safety targets. In addition, different blast vibration criteria should be suggested separately as blast work safety management criteria, allowable blast vibration criteria, and allowable blast vibration limit

criteria.

① Criteria for monitoring management of blast work: Criteria values to secure perfect safety in consideration of uncertain factors of blast works.

② Allowable blast vibration criteria: Criteria values allowing no substantial damage to nearby safety targets.

③ Allowable blast vibration limit criteria: Minimum values of damage limits that may result in even slight damage to safety targets.

(3) The blast vibration values should be should be based on the PPV of the individual elements.

(4) The recommended blast vibration criteria that are currently applied in Korea are shown in Tables 11.3-1 and 11.3-2. The tunnel design standards are found in Table 4.4-1 of KDS 27 20 00.

Table 11.3-1. Korea's recommended standards found in the Open Pit Blast Design Guidelines provided by the Ministry of Construction and Transportation (December, 2006).

Item	Remains, cultural heritages, computer facilities	Houses, apartments	Commercial buildings	Reinforced concrete buildings and factories
Vibration velocity (cm/sec)	0.2	0.3 ~ 0.5	1.0	1.0 ~ 5.0

Note 1) Since blast noise and vibration are caused by open pit blasting, the recommended standards are those that are expected to prevent civil complaints related to the noise and vibration felt by human bodies. When the recommended standards are exceeded, it does not necessarily mean that damage is caused to surrounding buildings.

Table 11.3-2 Allowable blast vibration standards suggested by the Environmental Dispute Resolution Commission

Soundness class	Target buildings	Vibration velocity, ㎝/s			
		Frequency band			
		< 10 Hz	10 ~ 40 Hz	40 ~ 100 Hz	>100 Hz
Ⅰ	Reinforced concrete building	1.5	1.5 ~ 4.5	4.5 ~ 5.0	5.0
Ⅱ	Concrete and brick building	1.0	1.0 ~ 2.5	2.5 ~ 3.0	3.0
Ⅲ	Masonry cement block building	0.5	0.5 ~ 1.5	1.5 ~ 2.0	2.0
Ⅳ	Building constructed by renovating class Ⅲ building and protected building of historical importance	0.25	0.25 ~ 0.75	0.75 ~ 1.0	1.0

Note 1) Soundness refers to soundness depending on the building type and conditions, and should be assessed by experts.

11.3.8 Report of Monitoring Result

Must conform to 1.3.12.

12. Construction of Cofferdam and Formwork

12.1 General

12.1.1 Scope of Application

(1) The purpose of this chapter is to provide the standards of temporary facilities that are installed to construct a structure, including cofferdams and floor posts.

(2) The monitoring related to the earth retaining walls in underground excavation conforms to the monitoring standards specified in 4.8 Excavation Construction.

12.2 Materials

12.2.1 Types of Monitoring Instrument

(1) The load gauge should have a capacity that is 200% the maximum estimated load.

(2) The precision of the displacement meter should be within 1/100 mm.

(3) The strain gauge should be a product appropriate for the installation conditions.

(4) The precision of the inclinometer should in principle be within 1 mm.

12.2.2 Monitoring Data Acquisition System

(1) Either an automated or semi-automated management method should be selected after considering the conditions of the monitoring target.

(2) Early detection of the signs is important for the formwork for concrete placement, because the load is concentrated at the time of concrete placement. In addition, the information obtained through monitoring should be rapidly transmitted and processed. Therefore, an automated monitoring data acquisition system should in principle be applied to collect, process, and analyze the real-time monitoring data.

12.3 Construction

12.3.1 Installation of Monitoring Instrument

(1) All the monitoring instruments installed for temporary facilities should be completely installed before the excavation works or the installation of the temporary facilities to measure the initial values before the monitoring location is influenced by any loads applied to the temporary facilities.

(2) Monitoring instruments that are difficult to install before the completion of construction works in a

certain construction work stage should be installed after the installation of the temporary facilities to be monitored and before moving on to the next construction stage.

12.3.2 Correction of Measurement Instrument

(1) The normal operation of a monitoring instrument should be tested before and immediately after the installation. If necessary, the monitoring instrument should be calibrated.

12.3.3 Protection of Monitoring Instrument

The installed monitoring instrument should be protected from the construction works and other effects, to avoid damages.

12.3.4 Installation of Data Transmission Cable

The monitoring instrument cable should be a cable that is exclusively for the monitoring instrument. A single cable with no connection point from the laying point to the monitoring room should be used.

12.3.5 Inspection and Testing of Monitoring System

(1) Following the installation works for measurement instruments, the correction and tests should be performed, and a test-run should be performed as follows.

12.3.6 Maintenanace of Monitoring Instrument

(1) To preserve the performance and secure the reliability of the monitoring results, the monitoring instrument should be managed according to the methods and procedures provided by the manufacturers.

(2) A guideline label and a name tag should be attached to the monitoring instruments and the data acquisition systems.

(3) A signboard on which the title of monitoring, monitoring location, initial monitoring date, and initial monitoring values are written should be installed for management of the installed monitoring instruments.

12.3.7 Execution of a Monitoring Program

(1) In cases where the load is continuously changed over time, real-time monitoring should be performed while the load is applied. After reviewing the monitoring results, any necessary countermeasure to be taken should be reported to the superintendent.

(2) Performance and management of monitoring may be carried out by a dedicated monitoring team operated by the Owner/Client or the subject of maintenance, or may be entrusted to a specialized monitoring company.

(3) The person in charge of monitoring should be an advanced construction engineer who

understands the characteristics of the monitoring instruments and the behavior of the members to which the monitoring instruments are attached.

12.3.8 Monitoring Frequency

(1) Real-time monitoring should be performed if the load on the temporary facilities is changed over time.

(2) Real-time monitoring is not necessary if the load on the temporary facilities is not changed over time.

12.3.9 Monitoring Period

The monitoring period is from the installation of the monitoring instrument to the confirmation of the convergence of the monitoring values.

12.3.10 Summary and Analysis of Monitoring Result

(1) The monitoring result should be summarized immediately after monitoring is performed.

(2) For real-time monitoring , the person in charge of monitoring should monitor the real-time measurement results and analyze the change and the rate of change of the absolute values to determine the risk of the monitoring target member.

12.3.11 Criteria for Monitoring Management

(1) The criteria for monitoring management should in principle be determined based on the properties of the materials. The criteria values should be determined with reference to the structural calculations.

(2) During the monitoring period, a separate criteria for monitoring management should be determined for persistent changes and rapid changes with reference to the change and the rate of change of the absolute values.

12.3.12 Report of Monitoring Result

(1) For real-time monitoring, the person in charge of monitoring should monitor the real-time measurement results and analyze the change and the rate of change of the absolute values. If the monitoring target member is considered as inappropriate and unsafe to support the applied load, the person in charge of monitoring should immediately report the fact to the superintendent, who may instruct the constructor to discontinue the follow-up works.

(2) Details other than those specified in (1) above should conform to 1.3.12.