RCCP Travelling Continuous Measurement System
-- Concrete Quarity Control System of Using Scattered RI Method --

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ABSTRACT

In order to raise the standard of RCCP compaction control while streamlining the control process. it is necessary to monitor the state of compaction quickly and continuously. and feed back compaction data speedily. Unlike conventional transmission-type gauges . this gauge allows the measurement of density without making holes in objects of measurement.This is therefore a powerful fool to measure the compaction of RCCP. This gauge has a number of outstanding features.

For example:

(1) Inspection can be performed quantitatively and nondestructively.
(2) Multipoint measurement enables the quality control of the wide area of RCCP.
(3) Easy operation. automatic recording and printing. and easy data processing.
(4) Measurements obtained from this gauge agree well with results of conventional tests.

1. INTRODUCTION

To raise the standard of execution control for. and streamline the process of . the compaction of embankments. such as base courses and subgrades of roads. and roller-compacted concrete pavement (RCCP) and roller-compacted dam (RCD) . it is necessary to monitor the state of compaction quickly and continuously. and feedback compaction data speedily.In order to meet this need.we have developed a system to monitor and display the state of RCCP compaction automatically andcontinuously using a scattering-type RI density measuring method. This paper outlines a prototype of a compaction monitoring system equipped with a satellite aided construction vehicle positioning system that tracks travelling paths and displays current positions. This paper also reports a part of the results of the system's trial use in actual compaction work.

The features of this monitoring system include the following:

- Densities and moisture contents of concrete can be measured nondestructively.
- Continuous measurement while the system travels permits a two-dimensional. quantitative evaluation of RCCP.
- Stationary measurement allows the measurement of fixed points.
- Good agreement with measurements obtained from conventional tests.
- Travelling capability enables a safe and speedy automated measurement during and after the pavement process----spreading (by use of finishers). rolling and finishing.
- Measurement data is analyzed immediately. and the results of statistical calculation are output on-site in the form of histograms or control charts (X-Rs . X-Rm).
- Measuring points and travelling paths can be monitored in real time

2. OVERALL SYSTEM

2.1 System Configuration

This compaction monitoring system consists mainly of a compaction measuring system, a positioning system, and a travelling mechanism.

The measuring system and the positioning system are controlled froma notebook computer installed in the main body of the monitoring system, and can be run by a single program.

The compaction measuring system measures the densities and moisture contents of RCCP, whether it is moving or not, by the radio-isotope based scattering-type RI method.

The positioning system measures the latitude and longitude of the vehicle to determine the relative coordinates of the current position within the construction area.

By integrating these two systems, measurements and corresponding measuring points and paths can be determined. Fig. 1 shows a system configuration.

Photo.1 The Apearance of System

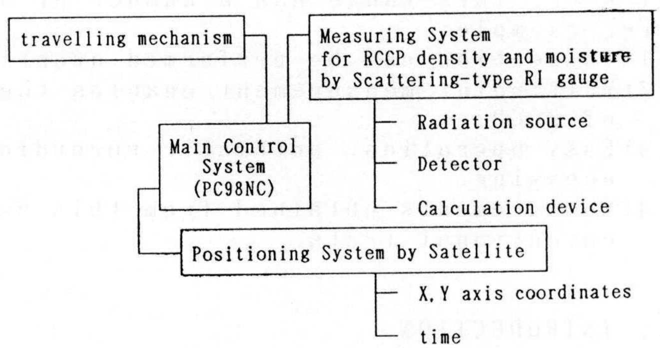

Fig.1 System Structure

2.2 Compaction Measuring System

(1) Overview

The measuring system performs a continuous measurement nondestructively as ittravels, maintaining a clearance of 10 mm between the objects of measurement anddetectors. This is a versatile system that allows the measurement of a variety of materials, simply by modifying the programmed calibration formula.

Specifications of the measuring system are as follows:

■ Measuring Method	Density: gamma ray scattering type Moisture: thermal neutron scattering type
■ Measuring Range	Density: 1.00-2.60 t/m Moisture: 0.05-0.90 t/m
■ Clearance	Approx.15 cm from pavement surface
■ Radiation Source	Gamma ray: Co-60, 70μci Thermal neutron ray: Cf-252, 30μci
■ Detector	Gamma ray: scintillation counter Thermal neutron ray: 3He counter x 2
■ Weight of Measuring Unit	45 kg
■ Total Weight	155 kg
■ Dimensions	750 x 100 x 700 mm
■ Measuring Interval	Variable (1-second increment)
■ Measuring Modes	Stationary/travelling measurement Measuring cycle: 0 to 999
■ Measuring Instructions	Keyboard operation
■ Computer	Notebook computer
■ Travelling Mechanism	Battery driven (forward/backward)
■ Power Supply	7-hour continuous run on battery

(2) Measurement Principle

RI-based measuring methods can largely be classified either as a transmission method or a scattering method. An RI test refers to the measurement of the subsurface densities and moisture contents of the objects of measurement. RI measurement is based on the nature of radio isotope radiation of interacting withthe atoms that constitutes the ground. Density measurement uses gamma ray and is based on gamma ray's nature of being greatly affected in interaction by the densities of the objects of measurement. Measurement of moisture contents uses neutrons and is basedonfast neutrons nature of transforming into thermal neutrons after colliding with hydrogen atoms and being scattered. The scattering RI method is a completely nondestructive testing method, which does not require any holes for radiation source bars.

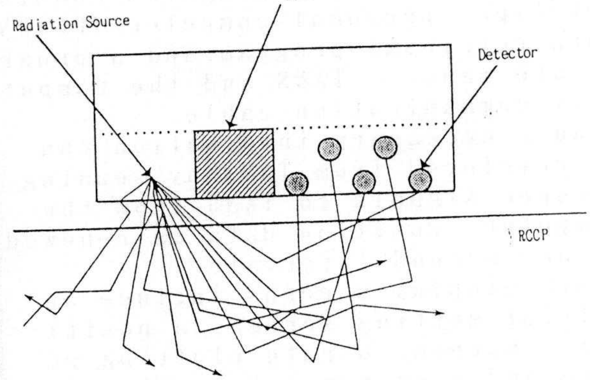

Fig.2 Measurment Principal

The measuring unit in the compaction measuring system is not based on the total energy method which has traditionally been used in gamma-ray density measurement.Instead , it detects scattered gamma ray within a certain range of energy in orderto improve measuring accuracy. For generating calibration curves, clearance between the groundand the measuring system is introduced as a parameter into the calibration formula so that measurement can be performed even if there is some spacebetween the ground and the system. The detection speed was increased so that measurement can be conducted at one second intervals.

2.3 GPS-based Positioning System

(1) Outline of GPS

GPS(Global Positioning System)is a satellite-based geodetic positioning system which is currently under development in the United States.

GPS was originally developed as a navigation aid for ships and cars to determine their own positions. Since a GPS equipped with a special receiver enables a highly accurate measurement of baselines , its future in areas of surveyingn and geodetic positioning is promising.

So-called earthwork, such as the construction of dams and roads and formation of residential lands , is usually executed in open spaces in suburban or rural areas where there is few overhead obstacles, that is, where transmissions from satellites can be received with relative ease. Since a construction site often covers a large expanse of land , there has been a strong demand for an efficient means of positional information management for execution control,such asefficient surveying systems.This is why we considered that this satellite-based positional information system, GPS, should be used more for road works, too.

The stand-alone geodetic positioning receiver used in this system is a TANSmanufactured by Trimble Navigation, a U.S. company. TANS, which is a two-channel sequential receiver, operates receiving the C/A code in the L1 band from GPS satellites. TANS operates in a three-dimensional positioning mode when it has acquired four or more satellites or in a two-dimensional mode based on fixed altitudes when it has acquired three satellites. When only two satellites have been acquired, positioning cannot be performed.

(2) Configuration of GPS-based Positioning System

TANS provides position and velocity data through two-channel RS-422 inter-face. It is possible, therefore, to construct an application system specificallydesigned to meet user needs, by connecting it with a personal computer. The hardware configuration of the positioning system is shown in Photo 2.

Major specifications of TANS are shown in Table.1

The positioning system consists of TANS, an antenna and a notebook-type personal computer (PC98NOTE). System software consists of a data retrieval program,and a program to control data display including route maps. TANS and the computer are interconnected by a RS422 two-way communication cable.

Thus, necessary information can be retrieved from TANS by sending proper signals to TANS from the computer. Position data is renewed at one second intervals.

Data display screens include an initial setting screen, a positioning screen, a path plotting screen and a system information screen. The path plotting screen displays paths on a two-dimensional latitude-longitude coordinate system on a desired scale.

Route maps can be superimposed on a map taken in from an imagescanner. Information that can be retrieved with this system is as follows:

1) GPS time: GPS week time, week number
2) Determined position ① : XYZ (m) geocentric coordinates
3) Determined position ② : latitude(rad),longitude(rad), altitude(m)
4) Determined velocity ③ : XYZ velocity (m/s)
5) Determined velocity ④ : east, north and vertical velocity (m/s)
6) Satellite combination : positioning modes, satellite numbers , PDOP,HDOP,etc
7) SNR of all satellites : satellite numbers, S/N ratio

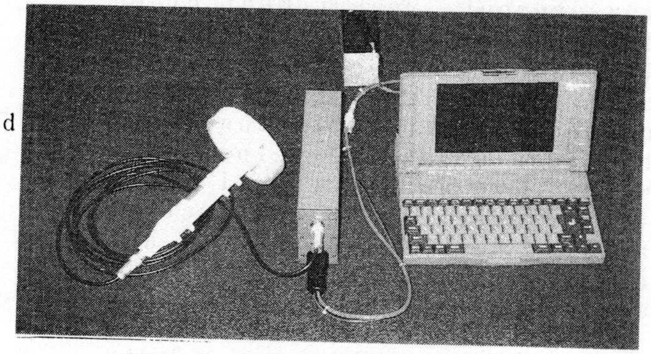

Photo.2 System Composition

Table.1 Specifications of TANS

Item	Specification
Sensor	L1 frequency C/A code, 2 channel sequential reception
Positioning Mode	1) 4 satellites: 3D positioning 2) 3 satellites: 2D positioning (fixed altitude) 3) Automatic: 3D when 4 satellites within range 2D when only 3 satellites within range
Horizontal Position Precision	25 m (SEP)
Vertical Position Precision	35 m (SEP)
Velocity Precision	0.2 m/s (RMS) at constant speed
Time Precision	Within 1 micro-second of UTC
Positional Dispersion	5 m (RMS) or under per 10 minutes when PDOP < 8
Position Renewal Time	1 second
Digital Interface	9600 baud 2-way RS-422, 2 channels
Dimensions	127 mm × 241 mm × 50 mm
Weight	1.27 kg
Power Consumption	9 to 32 VDC, 4W of less

2.4 Application to Actual Compaction Work of RCCP

(1) Measuring Method

At I construction site under the jurisdiction of the Kanto Regional Construction Bureau of the Ministry of Construction, the travelling continuous measuring system was used to monitor the densities of a cured RCCP.

Measuring periods used were 10 seconds and 15 seconds. A fixed travelling speed of 800 m/h was used, and the me-

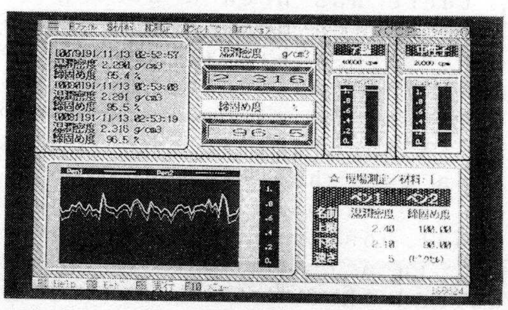

Photo.3 a PC98NOTE Display

asurement was conducted along the center of a road (150m).

Comparison was made between stationary measurement and travelling measurement , and between measurement by means of the measuring unit alone (60 sec) and trave-lling measurement. Details of measurement are shown below. A computer screen during measurementis shown in Photo 3.

■ Procedure :Data obtained from one second interval measurement was averaged. One second measuring cycle was repeated for the period of 10 or 15 seconds.

■ Input Data:1) Instrument settings: counting rate of standard object. BG of standard object,display mode, measuring time/cycle
2) Material data: reference density, calibration formula number, constants in calibration formula

■ Output Data: wet density, dry density, degree of compaction, moisture percent age, moisture content

■ Analyzing Method: statistical processing, X-Rm control chart, X-Rs control chart, histogram

■ Filing : text format, DBF format, SYLK format

(2) Results

Fig.3 compares results obtained from travelling measurement and those obtained from measurement by means of a scattering-type RI density moisture gauge. From the results of measurement, the following have been confirmed:

1) Results obtained from the measuring period (cycle) of 15 seconds are more stable, that is, less fluctuant than those obtained from 10 seconds. More consistent measurements can be obtained by using a longer, single measuring period than by conducting a number of shorter cycles.
2) Fluctuation per measuring cycle during 15 second measurement (approx.3.3m) was 0.1 t/m (coefficient of fluctuation: 4%). This is comparable to fluctuation observed in the measurement using the measuring unit independently (60 sec).
3) The average deviation from results obtained from the measurement using the measuring unit independently was only 0.8% for the entire measurement length of 150 m.

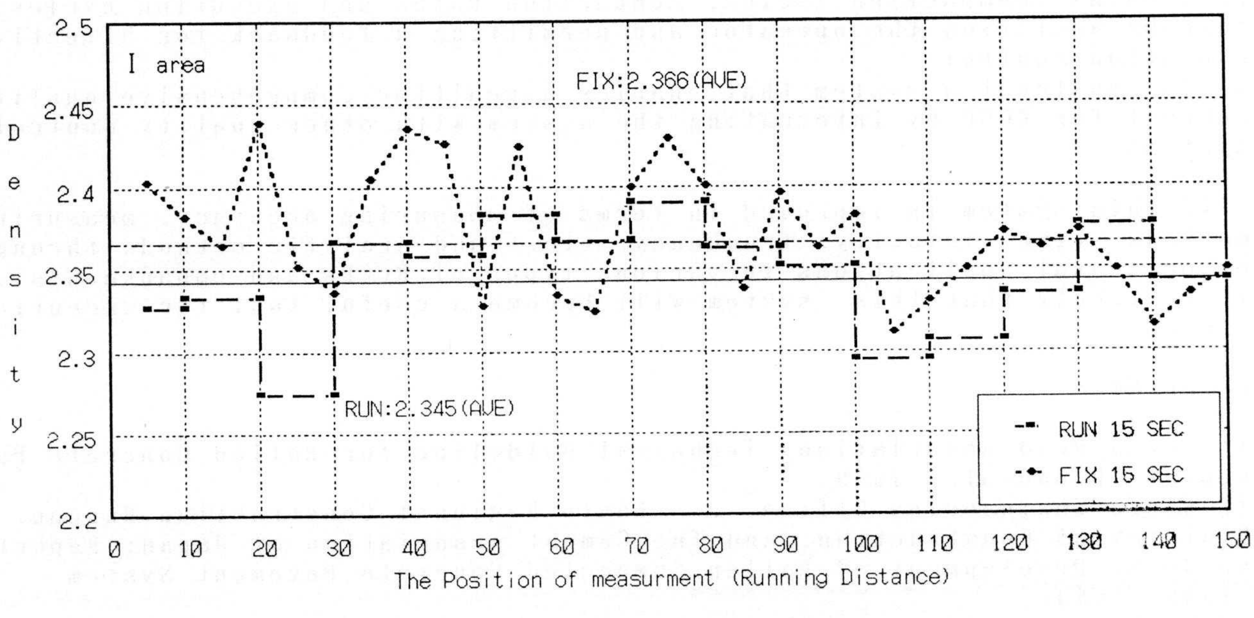

Fig.3 Running and Fix Measuring Result

3. Conclusion

In an RCCP work carried out at a site within the jurisdiction of the Kanto Regional Construction Bureau, measurement using a travelling monitoring system equipped with a measuring system was conducted, along with a conventional measurement and a measurement using a scatteringtype RI gauge independently. Findings from these measurements can be summarized as follows:

1) Accuracy and resolution comparable to those obtainable from manual instrumentation can be achieved by travelling measurement. The resolution of density required for the quality control of RCCP can be achieved.

2) Variation in the quality of RCCP can be monitored during travelling measurement.

3) Accuracy of absolute density (correlation with densities measured by conventional core sampling) can be improved further by defining a calibration formula specifically designed for travelling measurement on the basis of data obtained from further calibration testing.

4) The method presented in this paper is a rational measuring method and a very effective execution control method in that it enables a two-dimensional and speedy repeated measurement and evaluation of the entire RCCP being compacted.

On the other hand, there are somethings yet to be done:

1) To quantify the influence of measuring conditions (flatness of the surface of the object of measurement) on the results of measurement

2) To determine the influence of travelling speeds, measuring periods and measuring distances on resolution

3) To define a calibration formula considering mix proportions, material(graded crushed stone, asphalt, etc.) and the thickness of pavement

A next step will be an execution control method that will make the following possible by integrating compaction machinery with this system:

1) To equip vibrating rollers and tire rollers with this system so that the operator can monitor the progress of compaction in real time and see the completion of compacting operation quickly.

2) To measure the degree of compaction and control compaction machinery's paths, compaction cycles, compaction rates and execution cycles, thereby assisting the operator and permitting a feedback for effective execution control.

3) To construct a system that enables a realtime comprehensive quality control for RCCP by integrating the system with other quality control systems.

If this system is improved in terms of measuring accuracy, measuring methods (time, velocity, frequency, etc.) and analytic methods through experimental applications to various types of RCCPs and embankments, it is likely that this system will become a useful tool for execution control.

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