DEVELOPMENT OF RFID-BASED FLOW EXAMINATION SYSTEM

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Abstract: Flow examination of a drainage system is one of the typical tests when installing piping at construction sites in Japan. A huge amount of work is required for the examination, because it must be carried out for the entire pipeline of the drainage system, and the examination cannot be executed efficiently. Therefore, the authors developed the RFID-Based Flow Examination System to improve the efficiency and reliability of the flow examination, and applied it to several construction projects. We also developed an automated device to pick up the RFID tags and identify them, to improve the efficiency of operation at the ending point of the pipeline. This paper describes the features of the developed system, the outline of the automated device, and the results based on application in actual construction projects.

Keywords: RFID, PDA, flow examination, drainage system

1. INTRODUCTION

Flow examination of a drainage system is one of the typical tests when installing piping at construction sites in Japan. In the examination, generally examiners drop small balls into test objects such as the lavatory basin and kitchen sink, and confirm that they pass through the originally planned course and arrive at the correct ending points. In the conventional method, a huge amount of work is required for the examination, for it must be carried out for the entire pipeline of the drainage system, and the examination cannot be executed efficiently. It has been difficult to shorten the work time because examiners had to use stopwatches to time drainage, and they could not drop more than one ball simultaneously. The efficiency of the examination needed to be increased especially in apartment building construction projects, because there are so many test objects and the examination must be done in a limited time just before the completion of construction.

Therefore, the authors developed the RFID-Based Flow Examination System and applied it to several construction projects. This system uses RFID tags to improve the efficiency of operation and the reliability of examining the flow of the drainage system.

We also developed an automated device to pick up the RFID tags inserted into the balls and identify them, to improve the efficiency of operation at the ending point of the pipeline.

2. OUTLINE OF THE SYSTEM

2.1 Aim of Development

The system uses plastic balls with RFID tags inserted (Fig. 1). RFID tags have the following features: contactless reading, multiple reading, unique ID, rewritable memory, small size, and various shapes. We utilized these advantages and developed the system with the following aims:

1) Contactless reading
   Improve the efficiency of recording and writing various data.
2) Rewritable memory
   Write the starting time and correct drainage path at the starting point. Time the drainage automatically and confirm path consistency immediately after RFID tags arrive at the ending point.
3) Unique ID
   Identify balls and examine multiple test points simultaneously and continuously.
4) Data integration
   Generate a report on the examination automatically on a PC.

As shown in Table 1, the system uses passive RFID tags operating at frequencies in the 13.56-MHz band, which is less influenced by radio wave absorption by fluid. RFID tags are inserted into the balls to prevent the IC chips from direct impact or lodging in the inner wall of the pipeline.

The system uses a CompactFlash card type RFID R/W (reader/writer) attached to a personal digital assistant (PDA), shown in Fig. 2, to improve the efficiency of operation on construction sites. The maximum distance at which data can be read is around 12 cm.

2.2 Workflow of the Flow Examination

The workflow of the flow examination applying RFID tags and PDA with RFID R/W is shown in Fig. 3.

At the starting point of the pipeline, the examiner writes predefined data into the RFID tags and drops them into the pipeline with water. At the ending point of the pipeline, another examiner reads the RFID tags arrive. The system then immediately calculates the transit time of drainage water and displays the result. The flow is as follows:

1) Preparation

First, list all of the test objects that examiners drop balls into, and the ending points of the pipeline. Then register these data in the PC program. As shown in Fig. 4, set icons, which indicate the position of each starting point and ending point, on the floor plans. Input data, location, name of the test object, path, etc., related to each icon.

Next, send these data to every PDA, which operators use at both starting points and ending points.

Table 1 Specifications of RFID Tags

Frequency	Standard	Memory	Size of antenna
13.56 MHz	ISO 15693	128 bytes	28×12 mm

Fig.1 Balls and RFID Tags

Fig.2 PDA with RFID R/W

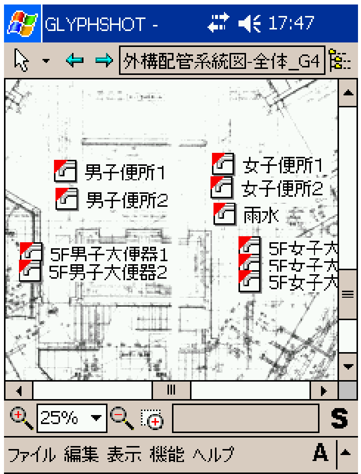

Fig.4 PDA Screen of Icons Location

Fig.5 Operation at Starting Point

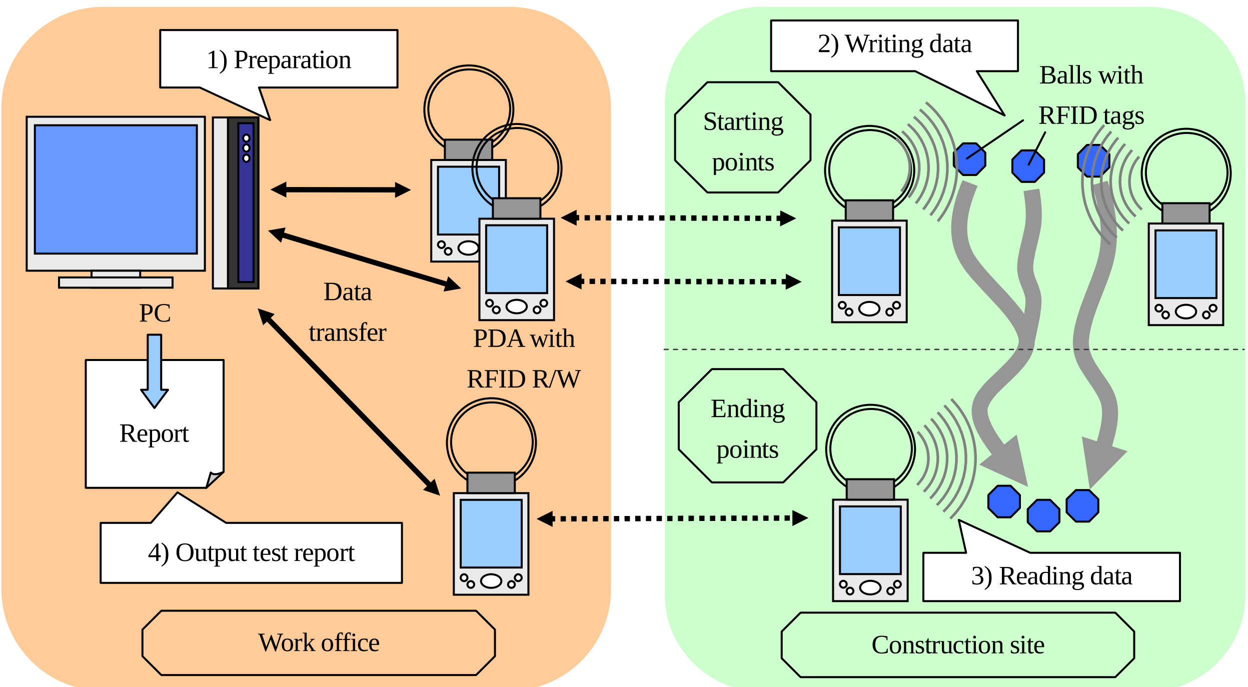

Fig.3 Workflow of the Flow Examination

2) Writing data into RFID tags (Fig. 5)

Select the icon of the starting point with the PDA program and write the data, starting time and correct path, into the RFID tag. Then drop the ball into the test object and drain it with water. After dropping the ball, the examiner is able to move to the next starting point without confirming whether the ball has arrived at the ending point or not.

Examiners can also add a new icon on site by using the PDA if necessary.

3) Reading data from RFID tags (Fig. 6)

The examiner at the ending point of the pipeline waits at the catch basin, picks up the ball when it arrives and reads the data of the RFID tag inside the ball by the PDA program. The starting time and correct path are read from the RFID tag, and the arriving time is recorded to the PDA memory. From these data, the drainage time and test results are displayed immediately on the PDA screen, as shown in Fig. 7.

Fig.6 Operation at Ending Point

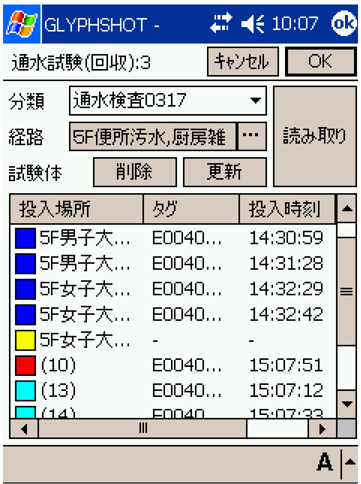

Fig.7 PDA Screen of Test Result

4) Output of test report

Transfer the data from all PDAs to the PC after operation on site, then generate a report on the flow examination in tabular form automatically with a PC program.

3. APPLICATION OF THE SYSTEM

We have applied the system to several actual construction sites so far. This paper describes three cases of application to apartment building construction sites, at which the number of test objects was comparatively large.

3.1 Methods of Application

The equipment used for these applications is shown in Table 2, and an outline of the examination is shown in Table 3. Subcontractors were assigned to perform the examination. The test objects were: lavatory pans of every dwelling unit, kitchen sinks of every dwelling unit in project A, and laundry pans of every dwelling unit in project B. In cases where there were two lavatory pans in one dwelling unit, both of them were examined.

Based on the workflow described above, the system was applied as follows:

1) Preparation

Registration of floor plans and test objects in the PC program, and data transfer to all of the PDAs were carried out before the examination. This operation took from 1 to 3 hours for each project, according to the size of the project and number of test objects.

Table 2 Equipment for Application

Name	Quantity
Laptop computer	1
PDA with RFID R/W	4 (starting points) 1 (ending points)
Printer (to output report)	1
Balls with RFID tags	150

Table 3 Applied Projects

Projects	Project A	Project B	Project C
Scale	7 floors 5 buildings	15 floors	12 floors 2 buildings
Examined lines	Sewage (lavatory pan) Waste water (kitchen sink)	Sewage (lavatory pan) Waste water (laundry pan)	Sewage (lavatory pan)
Dwelling units	204	70	89
Test objects	408	145	125
Ending points	Catch basin (5 points)	Catch basin (1 point)	Catch basin (2 points)
Examiners	4 (starting points) 1 (ending points)	4 (starting points) 1 (ending points)	3 or 4 (starting points) 1 (ending points)

2) Writing data into RFID tags

The examiners were instructed on how to use the PDA and the workflow of the examination with the system, taking about 20 minutes, just before the examination started. Each dwelling unit was allocated to one of four examiners. Each examiner dropped one ball into one test object and then moved to the next test object. The examiners tested the following three kinds of test object:

Lavatory pan: Drop the ball into the lavatory bowl and flush.

Kitchen sink: Fill the sink with water, put the ball into the pipeline from the clean-out below the sink, and then run the water in the sink.

Laundry pan: Remove the cover, put the ball into the pan, and run water by the hosepipe.

3) Reading data from RFID tags

The ending points of the pipelines were catch basins located outside of each building. When examiners picked up the balls as they arrived at the point, they took care to ensure that the balls did not flow out into the public pipeline behind.

Examiners used nettings with a stick to pick up the balls from the pipeline, read data of the RFID tags inside the balls, then transferred data from their PDAs to the PC after examining each building.

4) Output of test report

After examining all of the buildings, the reports on the flow examination were generated automatically in the work office.

3.2 Results of Application

1) Process of works

Figure 8 compares the work process between the conventional method of flow examination and the method with the newly developed system.

In the conventional method, examiners cannot drop more than one ball simultaneously, because the examiners at the ending point have to use a stopwatch to time the drainage and cannot identify many balls at once. Therefore the examiner at the starting point must use a cell-phone or other communication device to contact the examiner at the ending point. The examiner has to make sure that the ball he dropped arrived correctly before moving on to the next test point. This causes wasted waiting time, which is as long as the drainage time, for every test object. For example, using the conventional method in project C took 2 hours by 4 examiners (2 at starting points and 2 at ending points) for 24 test objects of 12 dwelling units. The average work time for each dwelling unit was 8 to 10 minutes, compared with around 4 minutes in average drainage time. The total work time in the conventional method is thus more than twice the average drainage time.

In the new method, data can be transferred from starting points to ending points via RFID tags and examiners can confirm test results without using communication devices. Consequently, examiners at starting points can drop balls one after another without having to wait.

Furthermore, in the new method, the number of examiners at starting points can be increased to reduce the total work time of examination, whereas in the conventional method examiners had no alternative but to conduct the examination in a pair (one at the starting point and one at the ending point). The new method is effective if time is limited just before the completion of construction.

2) Reduction of work time

In the new method, the work time for the flow examination was 9 hours in project A, 4 hours in project B, and 3.5 hours in project C, inclusive of giving instructions on how to use the PDA and other initial setup work, but exclusive of lunch breaks and other break time. The average work time of the flow examination for each dwelling unit, calculated as the total work time divided by the number of dwelling units, is shown in Fig. 9. The total work time in the conventional method is calculated as twice the average drainage time, as stated above.

Compared with the conventional method, the reductions in flow examination time in each construction project were

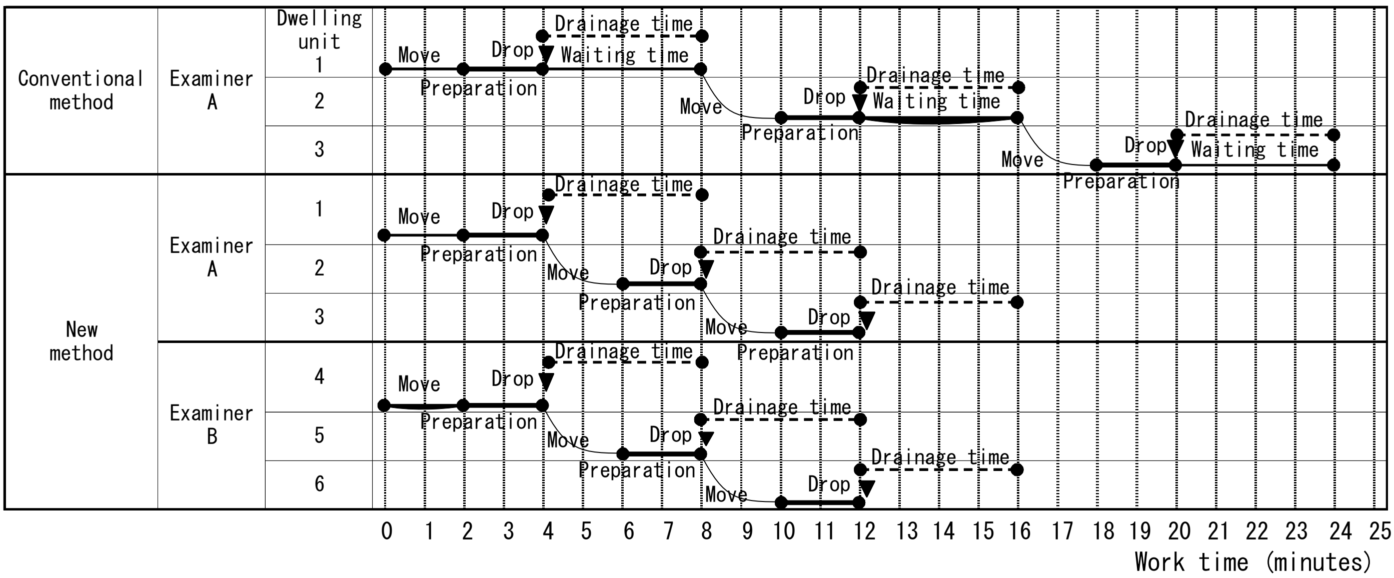

Fig.8 Comparison of Work Processes

16.5%, 20.7%, and 17.5%. For instance, in project A, the total work time was 1 day with the new method, compared with 5 days (1 building per day) in the original plan with the conventional method.

3) Reduction of man-hours

As in the case of work time, the average man-hours of the flow examination for each dwelling unit is shown in Fig. 10.

In the new method, the average man-hours for each dwelling unit in each construction project were 0.22, 0.29, and 0.18. Compared with project C, in which the test objects were lavatory pans only, projects B and C, in which kitchen sinks or laundry pans were also tested, needed more man-hours because more time is needed to open the clean-outs or covers and prepare to run water.

Compared with the conventional method, the reductions in man-hours for flow examination in each construction project were 41.4%, 51.7%, 40.0%. Hence, in the new method, man-hours were reduced by 40 to 50 percent.

For all the examiners, it was their first time to do the work. If examiners acquire proficiency in operating the system, the effects should be even greater.

4) Automatic report generation

The examiners transferred data from the PDAs to the PC, then the reports on the flow examination, as shown in Fig. 11, were generated automatically.

The system can automate most of the report writing operations. Compared with the conventional method, the man-hours for office work were reduced substantially. Examiners could print out and present well-structured reports as soon as the examination on site was completed.

5) Improvement in reliability of the examination

All operation records and test results are securely kept, because they are stored in RFID tags and PDAs. Computerized aggregate calculation and data recording prevent human errors such as misreading the stopwatch and missing out test points. Falsification of data and faked data can be prevented by setting attributes to prohibit the rewriting of particular data. Site supervisors commented that the system was more reliable in recording the time of every operation.

4. DEVELOPMENT OF THE AUTOMATED DEVICE

4.1 Aim of Development

Although the total work time of the flow examination can be shortened with the system, if the number of examiners at the starting points is increased, the examiner at the ending points cannot keep pace with many balls arriving in waves. Human errors might arise in this case.

Therefore, to improve the efficiency of operation at the ending point of the pipeline and the reliability of the flow examination, the authors developed an automated device to pick up the RFID tags and identify them.

RFID is suitable for automated data input because of its contactless and multiple reading properties. The series of operations – picking up balls, reading RFID tags, and data processing – is automated.

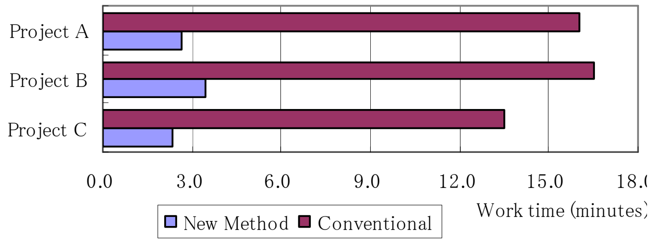

Fig.9 Average Work Time for Each Dwelling Unit

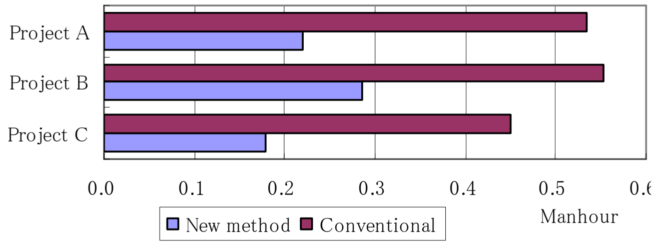

Fig.10 Average Manhours for Each Dwelling Unit

排水流下・通水検査記録表 NO. 1

工事名称			確認日	～	
協力会社	名称		検査責任者		印
	立会者	印	確認者（店社責任者）		印
大林組	担当者	印	確認者（店社責任者）		印

配管種類	○汚水管、○雑排水管、○空調用ドレン管 ○特殊排水管（ ）	流下物	
判定基準	・最終排水口、排水会所、排水桝にて対象流下物を確認できる。		
備考			

検査日	No.	系統名称	階・室名称・器具名称	判定	判定者	立会者
10月12日	1	A棟汚水	A101-トイレ	良		
10月12日	2	A棟汚水	A102-トイレ	良		
10月12日	3	A棟汚水	A103-トイレ	良		
10月12日	4	A棟汚水	A104-トイレ	良		
10月12日	5	A棟汚水	A105-トイレ	良		
10月12日	6	A棟汚水	A106-トイレ	良		

Fig.11 Test Report

4.2 Configuration of the Automated Device

The configuration of the automated device is shown in Fig. 12.

1) Suction machine

A commercially available vacuum cleaner sucks up the balls and water. It can run continuously by discharging trapped water back to the catch basin.

2) Suction opening

The suction opening prevents arriving balls from flowing out downstream, and sucks them up with water. If the shape of the drainageway in the catch basin is complicated, a nozzle head attachment is available.

3) Water/ball separator

RFID tags should be separated from water to improve the rate of successful reading. Water and balls are separated by inertia. Water goes straight to the suction machine, and balls change direction along the rail.

4) Feeding function

Revolving-door-style electric motor driven equipment maintains airtightness while feeding the RFID reader with balls, in order to enable the suction machine to remain activated.

5) RFID R/W

The stationary RFID R/W identifies the RFID tags inside the balls. Gentle inclines make the balls roll down slowly, which improves the rate of successful reading. The RFID R/W is connected to a laptop computer, which displays the drainage time and test results on the screen.

4.3 Expected effects

We applied the automated device as a trial, as shown in Fig.13, to study the effects.

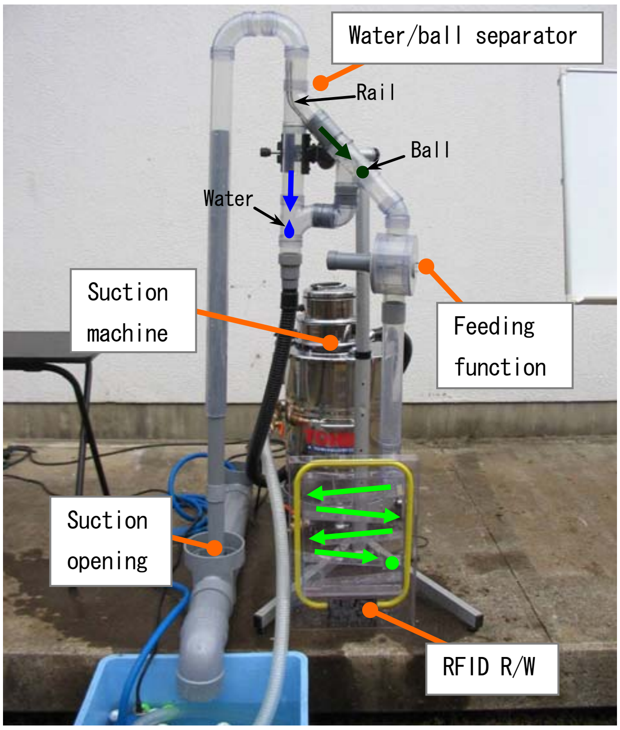

Fig.12 Configuration of Automated Device

a) Project B b) Project C

Fig.13 Application of Automated Device

The efficiency of picking up the balls and identifying RFID tags with the automated device depends on the rotating speed of the feeding function. It can identify 60 RFID tags a minute. Examiners at the ending points can thus be reduced, and the efficiency of the flow examination is improved.

In case the size of the catch basin is small, such as 150 or 200 mm in diameter, the operation of picking up the balls was not easy, because it is difficult to handle the nettings. Even if the operation has some difficulty due to the situation at the ending point, the device still improves the efficiency of operation.

5. CONCLUSIONS

We confirmed that the system has the following advantages:

1) The system enables examiners to drop multiple RFID tags into a pipeline concurrently and continuously. As a result, the system reduces the work time by 80% and manpower required for flow examination by 50%, compared to the conventional method.

2) Time stamp and test results are consistently stored in RFID tags and PDAs. Computerized aggregate calculation and data recording prevent human errors.

3) The system generates reports on the flow examination quickly and efficiently.

4) The automated device improves the efficiency of operation at ending points and the reliability of the examination.

In the future, we will upgrade the system and apply it to a number of construction sites. We will also work toward practical application of the automated device.

As mentioned above, RFID is an effective technology for data transfer between IT devices and automated devices, and so is expected to be used for various situations in construction automation.

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