A large amount of information is created and stored for construction projects. Especially at the construction work phase, much time is consumed to collect inspection-related data in order to conduct quality control tests every day, and developing an efficient inspection method is desired. In this study, we have created a tool to conduct quality control tests for structures at the construction phase, utilizing radio frequency identification technology, and we conducted a test at a construction site. The results show that inspection and subsequent data management can be done efficiently. Additionally, we showed that the developed tool can lead to information coordination that crosses over from design to maintenance.

**Keywords:** Automatic identification technology, Quality control work, Structure information, Tablet computer, Database

### 1 Introduction

Information is repeatedly passed back and forth between personnel involved in construction projects as those projects progress for railways, and paper drawings and ledgers are mainly used for much of that exchange. The information is stored separately at individual management locations, and that can lead to inconsistencies at construction and to rework due to a lack of information sharing. Also, drawings and ledgers are repeatedly revised in the process of preparing those, requiring much labor, so the current construction production system is far from being efficient.

To improve on the situation and make work more efficient, we believe construction and service work methods need to be revised and a new structure needs to be introduced for information storage and exchange. The authors and others are thus studying a technique of information management by a 3D platform. Fig. 1 shows an overview of that structure, and information storage and exchange will become more efficient by unifying project information through the platform and enabling information to be used by multiple departments across different work process phases. And by linking databases of information visualized by 3D modeling of topography and structures, visual identification on client PCs of information in each work process phase will be enabled. This is expected to improve understandability and reduce rework. By utilizing unified information in the phases of planning, surveying/design, construction, and maintenance/management, we believe productivity can be improved in the overall construction production system.

To achieve this structure, media for storing, recording, and visualizing information and for sharing information across work process phases need to be provided and developed, as do tools for using that media.

In this research, we studied a construction supervision support tool utilizing automatic identification technology for the purposes of making quality management work in the construction phase more efficient and developing media to make information recording, exchange, and use smoother in the construction production system.

### 2 Quality Control Work

In the construction phase, a supervisor of the contractee usually walks through the worksite daily to confirm the construction status of the structure and the finished work quality. This is called quality control work. Finished work quality control procedures start with the contractor preparing an inspection ledger according to design drawings, as is shown in Fig. 2. Next, at the worksite, the contractor searches the collection of design drawings for drawings of the structure to be inspected, compares the structure with the drawings, searches the inspection ledger for the page of the structure to be inspected, and then starts to take measurements. Structure dimensions and form are confirmed, the results are entered in the inspection ledger, and then those are checked to make sure they meet specification values. After that, the supervisor of the contractee conducts on-site confirmation inspection based on the contractor’s advance measurement values. Finally, those records are organized as a report. This work is done repeatedly by individual block as the construction proceeds. In this process, incidents occur, such as mistaking the structure to be inspected (results entered in the wrong inspection
We decided to develop a construction supervision support tool to support quality control work using IC tags (a form of automatic identification technology) and portable terminals. If the item to be inspected can be made unambiguous, human error can be reduced and work made to be more efficient. We thus focused on automatic identification technology. With that technology, we believe items to be inspected can be identified unambiguously and miswriting. To reduce mistakes, it would thus be best to introduce a structure where human subjectivity is not involved.

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3.1 Overview of Automatic Identification Technology and IC Tags
Automatic identification technology is defined as "technology (including hardware and software) to import data such as barcodes, magnetic cards, and RFID (Radio Frequency Identification) media automatically by devices without human involvement and identify the content of such data". The methods of data capture are one-dimensional symbols (barcodes), two-dimensional symbols (QR codes, etc.), RFID (IC tags), OCR, magnetic stripe cards, contact-type IC cards, contactless IC cards, and biometrics, collectively called "data carriers." Of those, data carriers other than biometrics involve predefined data, symbols, and the like being recognized by machine.

IC tags involve attaching to products and other objects card- or tag-type media composed of an IC chip with recording device and an antenna and then sending and receiving the data on those using radio waves without making physical contact. Tag information is ordinarily read and written using a reader/writer (r/w), with that data being managed on a computer database.

3.2 Overview of Supervision Support Tool
The concept of the construction supervision support tool is shown in Fig. 3. A structure is given an ID (here, the ID "A"), and based on that ID, information for "A" at the design, construction, and maintenance/management phases is updated with the tool as needed via the attached IC tag. Also, quality control work at the construction phase and inspection work at the maintenance/management phase are supported to allow work to be done more efficiently.

The tool is composed of IC tags and portable terminals (tablets), a database server, and a communication line, and the r/w uses near field communication (NFC). At the design phase, a database storing data by individual IDs given at arbitrary units (for example, with concrete pouring units, three blocks separated at construction joints in the structure shown in Fig. 4) is formed. And at the construction phase, ID tags associated with the database are placed on the structure. By identifying these IC tags by an r/w, structure information related to that ID can be called up on a portable terminal, allowing drawings to be referenced and quality control information to be registered.

In conventional quality control, much time is required at the phases where finished work quality inspection is conducted, where finished work quality control records are organized as reports, and where the details of reports presented to the contractee by the contractor are confirmed. Moreover, a huge volume of reports is presented throughout the project, so the place where those are stored filling up and the labor involved in searching those documents became problems. For that reason, threshold determination in finished work quality confirmation inspection was automated, the process from inspection record report preparation to presentation to the foreman was made to be a work flow, processing was made faster with this tool, and issues in storage were resolved by making a database of the reports.

In this research, we envisioned that the IC tags set up on the structure in the construction phase would continue to be used even after completion. Being able to know the background of structure production from the structure at the site leads to faster repairs in the maintenance/management phase, thus making achievement of this tool significant.

3.3 Association of IDs
With this tool, IC tags are attached to structures in the construction phase. It is assumed that environments may come about where IC tags are physically unreadable due to concrete
being poured on the surface holding the IC tag or building of adjacent structures or they become unreadable due to having reached the end of their lifespan. For that reason, the tool was given a function to associate multiple IC tags with the inspection record ledger. By doing so, switching IC tags becomes possible and data of multiple IC tags can be managed by a single IC tag as construction progresses. For example as shown in Fig. 4, if IC tag A-0 is newly installed to structure A and registered to the inspection record ledger of ID:A3, information of A-3 can be referenced from tag A-0, and the read/write function of tag A-3 can be switched to ID:A-0. Also, if A-0 and the three IDs of ID:A-1, ID:A-2, and ID:A-3 are associated, all information regarding structure A can be referenced from tag A-0.

4.1 ID Registration
Attempts were made to make information exchange more efficient by the contractee and contractor both using the tool, and different applications are used according to the user. For that reason, we register user IDs in advance in order to identify the user of the tool. By registering the approval sequence (Table 1) when registering the user, reports are numbered in ascending order from 1 when they are circulated.

4.2 IC Tag Identification and Inspection Record Ledger/ Drawing Referencing
This tool starts an application corresponding to the user at time of use by recognizing an IC card with a user ID registered. In the test, an IC card was held over an r/w, starting the tool on a portable terminal, and thereby confirming that the user was authenticated. Then, as shown in Fig. 5, an IC tag was attached to reinforcement and reading by an r/w was confirmed. NFC, with a short communication distance, was adopted for the r/w, so it recognized tags correctly without being affected by reinforcements and nearby tags. Structure information (inspection record ledger, drawings) of the ID associated with the IC tag was immediately read successfully from the database. Moreover, multiple differing IC tags were read and the ability to call up information associated with each of those was confirmed. This demonstrated that time required to check inspection record ledgers and the like at the worksite is almost entirely eliminated.

4.3 Registering Inspection Records and Providing Reports
Tool operation was confirmed by checking whether or not inputting inspection records and registering results to the database could be performed correctly for the inspection record ledgers where reading was confirmed in the previous section. When values exceeding standards were entered in the test, cells became colored as shown in Fig. 6, confirming that the conventional work of checking numbers with a red pen could...
be omitted. And after entering inspection values, inspection records were registered to the database by individual ID when executing the registration command.

By performing camera operations subsequently after authenticating the ID of an IC tag using a Wi-Fi enabled camera, photographs are registered to the database by individual ID with this tool. Execution of this function was similarly confirmed.

This tool uses the actual inspection records collected by individual ID as reports and presents those to foremen so as to speed up organization of inspection records and report approval, thereby reducing work to prepare reports and present documents. In order to accomplish that goal, the tool is linked with e-mail software, enabling the database holding inspection records to be referenced from a link in an e-mail, and approval (or rejection) actions in the workflow proceed according to the approval sequence of Table 1 set when registering user IDs. In this test, we confirmed that finished work quality confirmation inspection data registered at the worksite could be processed up to the final approver according to the workflow.

### 5 Conclusion

In this research, we prepared a construction supervision support tool that uses automatic identification technology in order to make quality control work more efficient and improve the way information is stored. As a result of a test at a construction site, we confirmed time up to starting confirmation work at the worksite is reduced, mistaking the structure to inspect can be prevented, standard value check at time of inspection can be done instantly, inspection record values can be registered to a database by individual ID, and that those can be referenced from IC tags attached to structures at the worksite. We also confirmed that inspection record storage, reading, and approval can be done in report production/approval work after inspection. In this way, we believe that processing from finished work quality confirmation inspection to providing reports will become faster and utilization of information by concerned personnel will be easier.

This tool can instantly obtain design phase information at the construction phase, construction phase information at the maintenance/management phase, and upstream information on the construction lifecycle, all through structures at the worksite. We thus expect that, in the future, worksite engineers will be able to make judgments faster and that construction and maintenance work can be started smoothly.

#### Table 1 User Registration

<table>
<thead>
<tr>
<th>Tag ID</th>
<th>Title</th>
<th>Name</th>
<th>Approval order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractor 01</td>
<td>Construction engineer</td>
<td>Ichiro Chiba</td>
<td>1</td>
</tr>
<tr>
<td>Contractor 02</td>
<td>Managing engineer</td>
<td>Jiro Tokyo</td>
<td>2</td>
</tr>
<tr>
<td>Contractor 03</td>
<td>Site agent</td>
<td>Saburo Takasaki</td>
<td>3</td>
</tr>
<tr>
<td>Contractee 01</td>
<td>Construction supervisor</td>
<td>Shito Sendai</td>
<td>4</td>
</tr>
<tr>
<td>Contractee 02</td>
<td>Assistant construction depot master</td>
<td>Goro Morikita</td>
<td>5</td>
</tr>
<tr>
<td>Contractee 03</td>
<td>Construction depot master</td>
<td>Rokuro Niigata</td>
<td>6</td>
</tr>
</tbody>
</table>

#### Reference: