Committee Report : JCI- TC123A

Technical Committee on Traceability System of Concrete

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Abstract

The Committee implemented research activities related to technology for ensuring concrete traceability in concrete production and the casting process for two years from FY2012 to FY2013. In order to ensure traceability, it is crucial to mark each concrete unit with an identification symbol, and record/manage the historical data in accordance with the symbol. Thus, the Technical Committee evaluated the modalities for technology for ensuring concrete traceability by implementing the following activities: 1) research and organizing of current technologies related to the ensuring of traceability in the fields of construction and civil engineering, 2) evaluation of technology to mark each concrete unit with an identification symbol, 3) organizing of concrete production and casting process historical data which should be recorded and managed, and 4) research activities on four agendas for traceability system trial experiments.

Keywords: Quality assurance, enhanced reliability, transparency, user protection, historical data, identification number

1. Introduction

Traceability is described as “the ability to prove the safety and related information of a product by clarifying its production and distribution history.” While engagements for traceability are being actively implemented in the fields of electronics, automobiles, food, etc., there is an increasing demand for ensuring traceability for the production and casting process of concrete as well. Concrete is shipped from fresh concrete production plants in a state of a semi-finished product before hardening, and is delivered to the construction site. It becomes possible to confirm whether or not the product has appropriate strength and durability only after the concrete hardens. When concrete is found to be inadequate after it hardens, the repair work required in such a case is costly and labor-intensive. For this reason, it can be said that in comparison to other industrial products, concrete products require a more detailed system for ensuring traceability.

Table 1: Committee Members

Chairman	Hisashi SUGIYAMA	Utsunomiya University
Vice-chairman	Hiroshi WATANABE	Public Works Research Institute
Secretary	Satoshi ARIKAWA	Tohoku Institute of Technology
	Takaaki OHKUBO	Hiroshima University
	Hideaki NAKAMURA	Yamaguchi University
Member	Naoki ARAGANE	Toyo Construction Corporation
	Hiroshi UEDA	Railway Technical Research Institute
	Akira ERIGUCHI	Taiheiyo Cement Corporation
	Masao KUSANO	Sumitomo Osaka Cement Corporation
	Junko KAGA	National Institute for Land and Infrastructure Management
	Sumie SUZUKI	Japan Testing Center for Construction Materials
	Hideaki SUMIKURA	Building Research Institute
	Takehiko TANUMA	Urban Renaissance Agency
	Akira NISHIDA	Shimizu Corporation
	Satoshi FUJIMOTO	Utsunomiya University
	Masakazu MARUOKA	Utsunomiya University
	Satoshi WATANABE	Taisei Corporation
Observer	Takamitsu SAGARA	Welcat Inc.
JCI secretary	Ryo OKADA	Japan Concrete Institute

The diagrams shown in **Fig. 1** and **Fig. 2** illustrate the mechanism of concrete traceability in the field of construction and civil engineering. In both fields, it is important to make sure that information regarding production and casting is handed over along the flow from the concrete material supplier to the fresh concrete manufacturer, then to the contractee/distributor and finally to the owner/resident/manager of the building or a civil engineering structure. Materializing technology for ensuring concrete traceability will not only lead to contributing to the enhancement of concrete reliability, but also to the rationalization of and labor-saving advancement in quality control and inspections. Furthermore, traceability provides important information in the maintenance stage of buildings and civil engineering structures, and is expected to ultimately lead to various benefits such as longer service life of those structures.

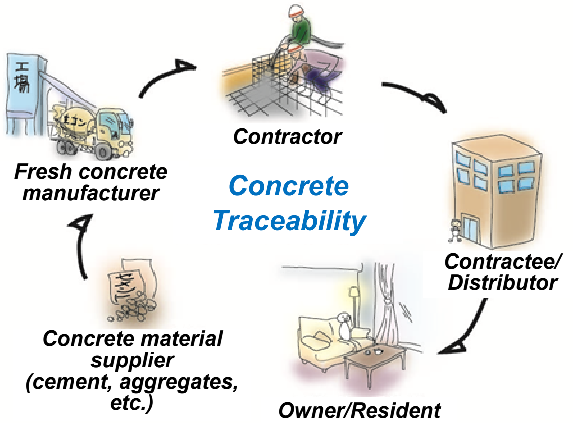

Fig. 1: Traceability (Construction)

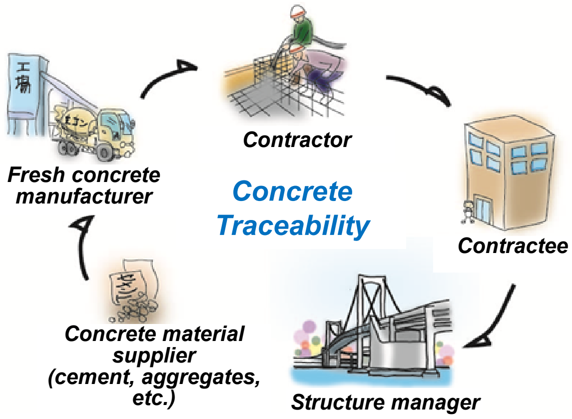

Fig. 2: Traceability (Civil Engineering)

With this background, the Japan Concrete Institute established the Technical Committee on Traceability System of Concrete (JCI-TC-123A), and implemented research activities related to technology for ensuring traceability in concrete production and the casting process for two years from FY2012 to FY2013. The composition of this Committee is shown in **Table 1**. Since the basic measure for ensuring traceability is to mark each concrete unit with an identification symbol and record/manage the historical data in accordance with the symbol, four specialty working groups were set up within this Committee, to evaluate modalities for technology for ensuring concrete traceability.

(1) Working Group for Research on Current Technology (WG1): Research for current technologies related to the ensuring of traceability in the fields of construction and civil engineering, and organizing of the information

(2) WG for Evaluation of Identification Technology (WG2): Evaluation of technology for marking each concrete unit with an identification symbol

(3) WG for Evaluation of Historical Data (WG3): Organizing of concrete production and casting process historical data which should be recorded and managed

(4) WG for Trail Experiments (WG4): Implementation of traceability system trial experiments

This is a report of the activities carried out by the working groups.

2. Current technology for ensuring traceability in the fields of construction and civil engineering

2.1 Engagements for traceability in Japan

Regarding the grasping of product production and distribution history, various engagements such as product tracking by barcodes have been implemented. Demands for these activities arose both from economic needs seeking enhancement of business competitiveness by efficiency and social needs seeking safety reassurance and reliability. In April 2003, basic policies for traceability activities in Japan were laid out by the interim report released by the Product Traceability Enhancement Research Committee (Ministry of Economy, Trade and Industry). In this report, emphasis was given on the use of radio frequency identification (RFID) technology, standardization of identification codes, and the building of an efficient distribution system. As for the fields that should implement engagements for traceability enhancement, the report listed building material/houses/residential facilities along with automobiles and home appliances. The required items of the historical data for traceability depend on the purpose and usages, as well as the diverse stakeholders. However, it is preferable that the items of historical data and their management methods are communized within each field. For this reason, it is expected that a Reference Model is created in each field which serves as a preceding reference case.

2.2 Research on current traceability technology

(1) Research purpose and methods

In order to collect all information regarding the technology used in Japan in relation to traceability in the fields of construction and civil engineering, a total of 139 documents were collected including hitherto published research reports (publicly available documents such as academic papers and technical reports) and information on attempts of technology trial use implemented by individual companies. This technical information was separated into four major categories (fields of concrete/civil engineering/construction and others), and was further categorized into technical groups based on the purpose, target or method for ensuring traceability. Among those, distinct cases and research groups that are conducting active technology development were extracted as technical groups A through H, as shown in **Table 2**, and analyzed.

Table 2: Current traceability related technology in fields of construction and civil engineering

Field	Technical Group	Purpose	Technology: Outline	Technology: Characteristics	Number of reports
Concrete	A	Information management	IC tag embedded concrete	RFID (IC-tag)	12
Civil engineering	B	Maintenance	Monitoring of railroad constructions	IC tag with sensor function	1
	C	Maintenance	Structure decay monitoring	IC tag with sensor function	3
	D	Quality control	Distribution information database building	Tablet terminal	1
Construction	E	Bar arrangement inspection assistance	Management of bar arrangement inspection results	RFID (IC-tag)	5
	F	Maintenance	Structure oscillation monitoring	Wireless accelerometer	2
	G	Maintenance	Structure displacement monitoring	Wireless sensor	1
	H	Construction management	Management of steel member production historical data	RFID (IC-tag)	3

(2) The field of concrete

Because fresh concrete is delivered in a fluid state, it is nearly impossible to use labels such as stickers attached to electronics for the identification of product, an important aspect of ensuring traceability. In light of this, there are high expectations for RFID technology such as IC tags which enable contact-free communication.

Expected benefits from using IC tags for ensuring the traceability of fresh concrete include not only the prevention of data alteration/falsification and the introduction of a paperless process, but also, using this technology will facilitate the process for determining the cause when faults are found after the concrete is casted.

Data Control System Using IC Tags Embedded in Concrete (Technical Group A) is an example of a study utilizing IC tags which is expected to provide the above mentioned benefits.

IC tags are used as an identification medium to link concrete and its production data (mixing plan, measurements, quality control test results, etc). An ID tag with a unique ID for linking production data is inserted in concrete, and, as shown in **Fig. 3**, the ID is identified and corresponding data from the database is recovered by wireless communication between the tag and an external reader/writer (R/W). Various information regarding the production of fresh concrete is obtained by adding the results of unloading inspections and strength tests, and a system for ensuring concrete traceability[1)] is built, as shown in **Fig. 4**.

It has been confirmed that no adverse effects are caused to the strength or durability of concrete by inserting an IC tag[2]. On the other hand, the results of experiments on the allowable depth of concrete inserted IC tag for communication[3), 4)], communication angle and other related issues have elucidated that there are advantages and disadvantages in terms of communication directivity and the number of inserted IC tags[5)], as well as communication stability. Therefore, to put this technology in to practical use, there is a need to examine utilization methods which exploit the advantages.

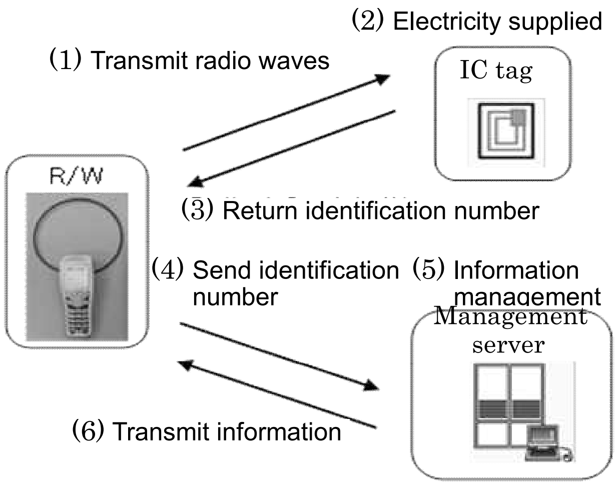

Fig. 3: IC tag and R/W data communication[1)]

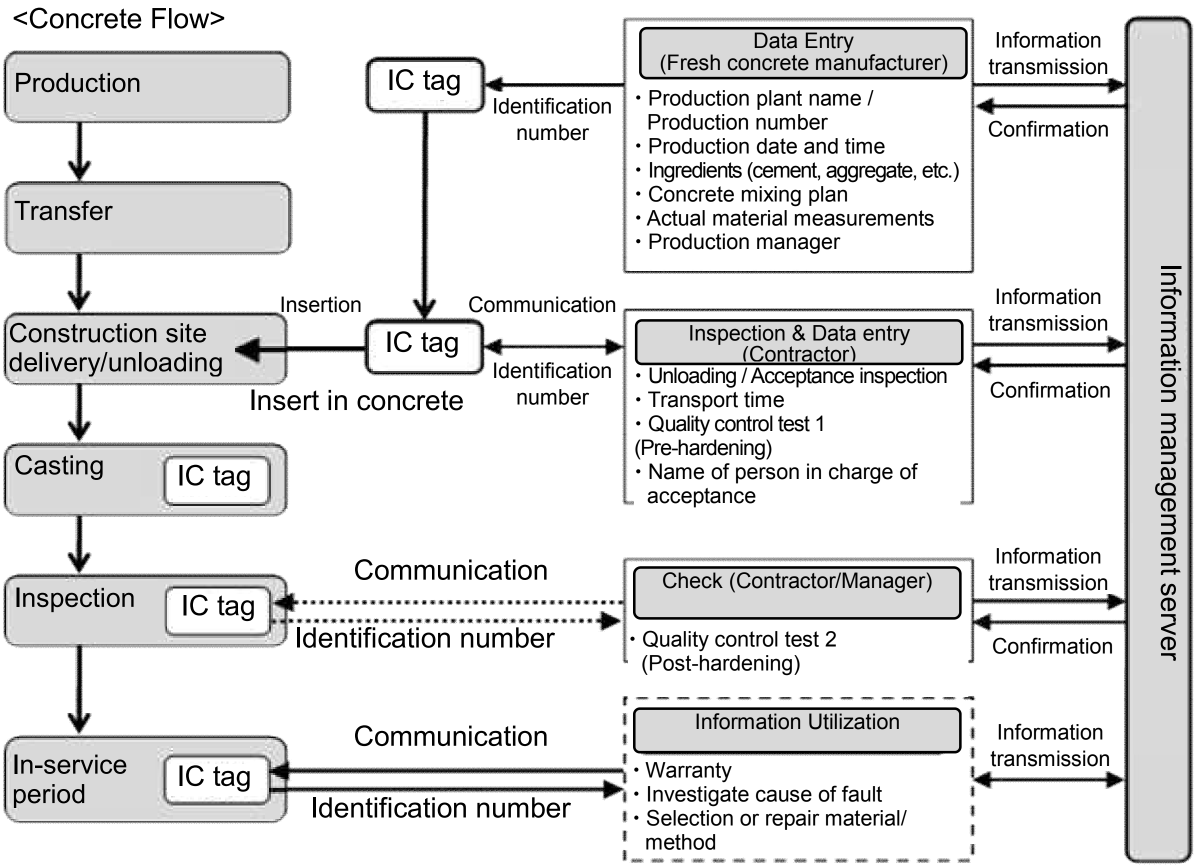

Fig. 4: Example of technology for ensuring traceability of fresh concrete production process[1)]

(3) Civil engineering

The great number of structures constructed for the railroad business during Japan's record period of economic growth after WWII must still be in service 50 years after its construction; hence there is a need to develop an efficient maintenance method for ensuring operational safety. For this reason, a system for damage level monitoring in structures using IC tags with sensor functions (Technical Group B) is being evaluated. Similarly, a system for corrosion status detection of reinforcement in the interior of structures using IC tags with sensor functions (Technical Group C) is also being evaluated.

Information technology is increasingly being adopted for construction projects in the field of civil engineering. For example, clear traceability is obtained through the uniform management of data by building a database of information regarding construction work and maintenance. In another approach, tablet terminals are used for the periodic inspections of bridges, and the results are transmitted to and accumulated in a data server (Technical Group D).

(4) Construction

When utilization of technology for ensuring traceability in the field of construction is categorized chronologically, such cases can be divided into the following major categories: utilization for material management, utilization for construction work management, and utilization for maintenance.

Material management based on grasping the properties and the quantity of the materials delivered to construction sites is not only important for ensuring the properties of the buildings, but also for ensuring a smooth construction process. While most of the research and application regarding technology for ensuring traceability in this field concerns constructional materials including fresh concrete, precast concrete, rebars, steel frames and timber, such technology is also applied to industrial waste and so on.

At the casting management stage, materials delivered to the construction site must be placed in designated locations in accordance with the plan, and must be joined in an appropriate manner. Especially, for construction projects employing materials such as fresh concrete which do not have the ultimately required properties at the time of delivery, placement management is extremely important because the quality of the placement work has a profound effect on the properties of the component. Most of the research and application regarding technology for ensuring traceability in this field is implemented in connection with the previously described material management as part of the flow of a series of processes, and mainly concerns streamlining of components assembly work regarding steel frames (Technical Group H), precast concrete, which has designated placement locations, timber and other materials. Research and application activities are also implemented for streamlining of rebar construction work (Technical Group E) and other issues.

Specific properties can be expected in the constructed building if the previously described material management and placement management are implemented appropriately. However, the properties of buildings change continuously over time during the in-service period due to various reasons including deterioration caused by the environmental atmosphere or exterior forces such as earthquakes, and by repair and reinforcement work. Thus, technology for ensuring traceability becomes important also for maintenance during the in-service period.

Areas of research and application regarding technology for ensuring traceability in this field include oscillation characteristics of building at times of earthquake (Technical Groups F and G).

3. Technology for marking concrete with identification codes

3.1 Outline of various identification technology

Not only for information related to concrete but for all information management, the most important point is that an item is identifiable. For example, there are IP addresses for identifying computers on-line, and each computer is managed within the network by this IP address which serves as an ID.

Similarly, traceability can be ensured with concrete structures by enabling individual identification of each component to provide clear data on materials, placement work, etc.

In the retail industry, conventionally, barcodes have been used as the medium for managing individual identification number of the objects. Barcodes have a series of straight lines in a striped pattern which represent particular numbers and characters according to the width of each line. They are mainly used when operating registers. Along with the popularization of smartphones and such, the use of a two-dimensional code (QR code), which represents large amounts of information with dots arranged in a matrix, has also popularized globally. In recent years, the IC tag system (RFID), which leverages the wireless property, has been attracting attention. IC tag is created by attaching an antenna to a micro IC chip, and can be used to obtain information of the object, such as the distribution channel, by wireless communication with sensors and so on. Furthermore, with the enhancement of the GPS positioning accuracy, it may be used for applications utilizing location data. **Table 3** presents a comparison on the applicability of various identification technologies for concrete traceability.

Table 3: Comparison of various identification technologies

	Paper-based record keeping	Barcode	Two-dimensional code	IC tag	Location data
Ease of uniform management	△	◎	◎	◎	◎
Data storage capacity	◎	×	△	○	×
Writable or not	○	×	×	○	×

Data reliability	×	◎	◎	◎	◎
Environmental resistance	△	×	△	○	◎
Shielding effect	×	×	×	○	◎

3.2 Identification technology utilizing IC tag (RFID)

RFID stands for Radio Frequency IDentification. It is an automatic recognition tool for contact-free reading and writing of IC tag data (various information regarding products, items, people, etc., ID number / production number, etc.) using radio waves. While RFID systems largely differ depending on frequency bands, chip performance, antenna form, and R/W output, in general they have the following advantages:

・ Large data storage capacity, data can be rewritten
・ Multiple reading (anti-collision) possible
・ Can be processed into various forms

On the other hand, RFID systems have the following disadvantages:

・ Communication is affected by metal, water and noise
・ Costly compared to barcodes
・ Communication distance differs depending on the direction of the IC tag and the R/W (has directivity)

Research is being conducted on using IC tags, which have the above described characteristics, for a traceability system for fresh concrete, and demonstration experiments have been conducted as well. Details are presented in **5.2**.

3.3 Identification technology using GPS

When accurate positioning is made possible, this location data can be used for identification since spatial positioning coordinates each have a unique value which do not overlap. As for positioning, America's Global Positioning System (GPS) is well known, and has been widely popularized. Efforts are being made in Japan to establish the country's original positioning system named Quasi-Zenith Satellite System (QZSS). While the elevation angle of conventional stationary satellites such as GPS range between 40° to 50°, since the elevation angle of a Quasi-Zenith Satellite is 60° or wider, it comes almost directly above Japan; enabling the receiving of signals from locations in mountains or locations behind sky scrapers in the cities. Furthermore, the QZSS is reinforcing the GPS signals currently used in Japan, and has a function that enables highly accurate positioning. It is said that while there can be a difference of approximately 10m between the actual location and the positioning by

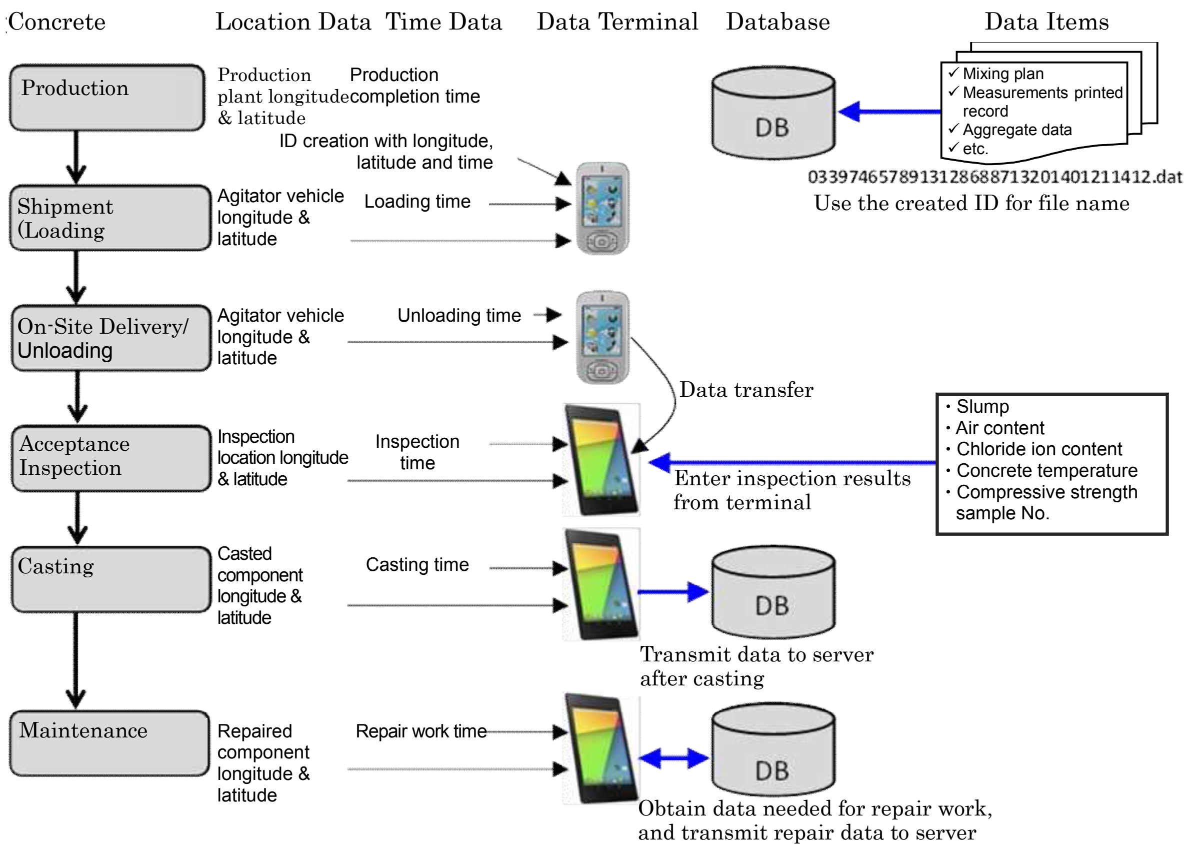

Fig. 5: Overall structure of concrete traceability using location data and time

general GPS, there is only a few centimeters error with the positioning by the QZSS.

The overall structure of concrete traceability using spatial positioning data and time is shown in **Fig. 5**. This traceability system enables on-line data reference along the flow of concrete from production up to maintenance. Data are linked by location and time data. Identification methods and data linking for each stage are explained below.

(1) Production stage

At the production stage, production data (mixing plan, printed record of measurements, aggregate data, cement data, aggregate surface water concentration, mixing time, etc.) of fresh concrete for each agitator vehicle is saved as an electronic file at the fresh concrete production plant, and an ID that identifies this electronic file is handed over to the next process. The ID created at this time is a 34-digit code consisting of the fresh concrete production plant longitude and latitude as well as production date and time in order to identify the electronic files created by numerous fresh concrete production plants located across the nation.

(2) Delivery (loading completed)

When delivering, a terminal receives an ID that links production data of the fresh concrete from the production plant. This ID is saved in the terminal and at the same time, data of loading completion location and time obtained from the GPS mounted on the terminal are also saved in the terminal. Production data can be grasped by identifying the electronic file containing the production data using the ID, and checking its contents. Specifically, when delivering, the driver of the agitator vehicle clicks the button of the terminal at the time when loading is completed. By this, the terminal receives the ID from the fresh concrete production plant, and also records the location and time data using the in-terminal GPS.

(3) Delivery to construction site (unloading)

When an agitator vehicle reaches the construction site, the arrival time is recorded on a shipment (delivery) slip, and a staff checks whether or not the concrete is delivered within the specified time. In this traceability system, the agitator vehicle driver records the location of the construction site, which is the delivery site, and the arrival time in the terminal by clicking a button on the terminal. Since the departure time is already recorded in the terminal, the transport time can be calculated immediately by comparing the departure time and the arrival time.

After the fresh concrete is delivered to the construction site, data must be handed over to the contractor since the contractor will be handling the concrete from this point on. In this traceability system, data is handed over by transferring the data in the terminal of the agitator vehicle driver to the contractor’s terminal. Depending on the terminal or on-site network conditions, data transfer between the terminals is accomplished via Wi-Fi, Near Field Communication (NFC), an SD memory card or Bluetooth.

(4) Acceptance inspection

At times, an acceptance inspection is implemented when fresh concrete is unloaded. In such cases, data from the acceptance inspection as well as the location and time are saved in the terminal. Since data on compressive strength cannot be entered at that time, the results of the compressive strength test are sent to the server at a later time when the test is completed.

(5) Casting

When casting, the locations (parts) to which the fresh concrete received from the fresh concrete production plant was used must be recorded. If possible, the terminal is taken to the tip of the tube of the concrete pumping truck, and its button is clicked. By this, data on the tube tip coordinates and the time are saved in the terminal. When the terminal cannot be taken to the tube tip, in cases of structures that are constructed in the vertical direction such as buildings, the structure name, structure details, and lift name (component name) are entered from the screen on the terminal so that the casting part can be identified. The lift name and component name must be entered for clarifying the casting position, because with the current GPS positioning, the accuracy of the measurements in the height direction (z direction) is considerably inferior to the accuracy of the measurements in the horizontal direction.

When casting is finished, the data of concrete from one agitator vehicle saved in the terminal are transferred to the server.

(6) Maintenance

In order to implement maintenance work, it is necessary to grasp the properties of the concrete that was used. If information is available on the casting positions and component names, data of the fresh concrete used for the construction can be grasped by searching the data stored in the server. Furthermore, in light of future maintenance, by adding new data including repair and reinforcement history as well as inspection data at the time of a maintenance inspection, and by accumulating such data in the server, the additional data will also play a role in upcoming maintenance work.

4. Historical data of concrete production and casting process which should be recorded and managed

4.1 Methods for extracting, categorizing and organizing historical data

A questionnaire survey was conducted regarding data that are saved for ensuring concrete traceability. The main purposes for conducting this survey were to grasp the degree of importance of concrete related data by items, and then to narrow down items to be saved by extracting items with high degree importance in order to minimize the volume of stored data, to prevent the decline in involved people’s awareness on information due to excess amount of data, and to streamline data management. The term “degree of importance” used here refers to an assessment of an item made from the viewpoint of the possibility of effective use for concrete production management, concrete construction execution management, maintenance during the in-service period of concrete constructions, etc. For this reason, it is assumed that the assessments made by the respondents differ according to their positions. Thus, it was decided to select nearly equal number of subjects for the following three groups (categorized by type of operation): a group of fresh concrete and concrete products production related businesses such as concrete material manufacturer/supplier, fresh concrete manufacturer, and precast concrete manufacturer (Group A), a group of concrete structure design/construction related businesses such as designers, construction consultants, and contractors (Group B), and a group of concrete structure in-service management and maintenance related parties such as owners, developers, and building survey/diagnosis companies (Group C). In total, the questionnaire was conducted with 91 subjects (Group A: 30, Group B: 28, Group C: 33).

Meanwhile, collection of data itself is difficult for items that are not necessarily tested. Furthermore, when it is assumed that information is semi-permanently saved as electronic data, it is not an easy task to save large sized data in data media with small memory capacities. Thus, in light of the cost effectiveness of data storage, the degree of difficulty of data storage regarding the above mentioned issues of data collection and data size must also be considered in addition to the degree of importance of the particular information. However, based on the assumption that assessments on the degree of difficulty will not differ as much as those on the degree of importance, responses on the degree of difficulty were collected mainly from committee members and for non-members, providing responses on difficulty was made optional.

Items of data included in this questionnaire numbered 260, including data items used for management according to JIS A 5308, Building Work Standard Specifications JASS 5, Standard Specification for Concrete Structures, as well as the Concrete Crack Survey, Repair/Reinforcement Policy and the Concrete Diagnosis Techniques of our institute, as well as the data items used for maintenance inspections of housing complexes and railroad structures. As for the methods for collecting information, since it can be assumed that data indicating the data storage location are stored on-site and based on that information, data are obtained from the data storage location, data on the collectors of each information were also included in the survey.

In order to collect information that represents the respondent’s awareness on the degree of importance as clearly as possible, respondents were asked in the questionnaire to rate the items by a four level scale consisting of “1, 2, 4, 5” with the option to choose “Cannot judge” when a respondent had no means of rating the item.

4.2 Outline of questionnaire results

(1) Overall trend of respondents

As an overall trend, the following information ranked in the top 30 high degree importance items for storage: general information such as structure construction year, structure style and construction location, data on concrete strength, results of past surveys, and data on repair work and countermeasures. These items were followed by data for identifying the cause of faults such as chloride quantity and water to cement ratios. Furthermore, these items were followed by construction execution related data such as completion inspection and acceptance inspection results.

On the other hand, data on used material test results and data on people such as supervisors and managers were rated as items with low degree of importance. The reason for test results of materials used for concrete being rated as low degree of importance may well be due to the fact that the basic principle is to only use materials that have been certified as complying with JIS and as such, it is assumed that respondents judged that there is no problem as long as certified materials are used, and that the test results do not directly link to the causes of faults. As for the reasons for the degree of importance of data on people being rated low, this may well be due to the fact that the data are not used if there is no fault, and also that the usefulness of the data decreases over time because of personnel changes and such.

Table 4: High degree storage importance, and readily storable, data

Degree of importance (ranking)	Degree of importance (points)	Data items	Difficulty (ranking)	Difficulty (points)
1	4.49	Structure data – Construction year	258	1.37
3	4.46	Structure concrete strength test – Compressive strength test results	217	1.88
9	4.36	Concrete related data from design documents – Design standard strength	256	1.55
16	4.28	Structure data – Structure style	257	1.41
25	4.16	Mixing plan – Name used – Nominal strength	249	1.74
27	4.10	Mixing plan – Mixing conditions – Water to cement ratio	240	1.76
28	4.07	Structure data – Construction location	259	1.33
31	4.04	Mixing plan – Name used – Code by concrete type	240	1.76
32	4.04	Structure data – Name	260	1.20
35	4.02	Structure concrete strength test – Age of sample material	236	1.79
36	4.02	Used material test results – Cement – Type	240	1.76
38	4.01	Concrete related data from design documents – Water to cement ratio	206	1.94
39	4.00	Mixing plan – Unit volume – Water	240	1.76
39	4.00	Structure concrete strength test – Sample development method	255	1.70
42	3.99	Contractor information – Company name	254	1.72
43	3.94	Mixing plan – Unit volume – Cement	240	1.76
44	3.93	Mixing plan – Specified item – Category by aggregate alkali-silica reaction	206	1.94
46	3.92	Used material test results – Aggregate – Type	224	1.82
46	3.92	Mixing plan – Name used – Slump, slump flow	249	1.74
46	3.92	Mixing plan – Specified item – Cement type	233	1.79
50	3.91	Mixing plan – Unit volume – Mixture material	233	1.79
52	3.91	Mixing plan – Name used – Code by cement type	249	1.74
54	3.90	Mixing plan – Specified item – Aggregate type	224	1.82
56	3.89	Mixing plan – Mixing conditions – Water to binder ratio	236	1.79
57	3.89	Mixing plan – Name used	224	1.82
61	3.84	Quality control at casting – Climate conditions – Weather	200	1.97
62	3.83	Mixing plan – Unit volume – Fine aggregate	240	1.76
62	3.83	Mixing plan – Unit volume – Coarse aggregate	240	1.76
66	3.81	Used material test results – Mixture material – Type	224	1.82

Table 5: High degree storage importance data with storage difficulties

Degree of importance (ranking)	Degree of importance (points)	Data items	Difficulty (ranking)	Difficulty (points)
2	4.48	Detailed data regarding past countermeasures (Survey reports, etc.)	10	3.15
6	4.43	Structure concrete appearance visual check – Rebar corrosion/rust leachate	47	2.73
7	4.42	Structure concrete appearance visual check – Deterioration/loosening/peel off of finishing material	63	2.65
8	4.39	Past survey results	42	2.75
10	4.32	History of past countermeasures – Countermeasure approaches	24	2.89
11	4.31	Drawing	2	3.55
12	4.30	History of past countermeasures – Countermeasure implementation date	58	2.70
13	4.29	Past faults / Repair work conditions	31	2.81
15	4.28	History of past countermeasures – Countermeasure implemented part	37	2.78
19	4.26	History of past countermeasures – Countermeasure category	19	2.92
20	4.25	Post-countermeasure implementation conditions	8	3.19
21	4.25	Design documents	4	3.39
22	4.22	Structure concrete strength etc. by sampled core – Test by phenolphthalein solution on neutralization depth	61	2.67
24	4.16	History of past countermeasures – Change in category based on integrity evaluation	30	2.85
26	4.12	Structure concrete strength etc. by sampled core – Chloride quantity	25	2.86
29	4.06	Structure concrete cover depth – Measurements	37	2.78
30	4.05	Structure concrete cover depth – Survey point	32	2.81
34	4.02	Structure concrete finished state inspection – Cracks	36	2.79
37	4.01	Inspection result details	41	2.76
45	3.92	Repair work conditions, Pictures	27	2.85
54	3.90	Structure concrete finished state inspection – Casting failures	49	2.71
65	3.83	Structure concrete cover depth – Measurement method	47	2.73
67	3.81	Structure vicinity environmental changes	13	3.11
68	3.80	Structure concrete cover depth – Relation between measurements and the minimum cover depth	15	3.04
70	3.79	Inspection conditions, Pictures	19	2.92

(2) Trends of the responses from technicians engaged in operations related to fresh concrete/concrete product production

Regarding the responses from concrete production related technicians, similar to the overall trend, past survey results as well as data on repair work and countermeasures, etc. were rated as having high degree of importance. Following these items in the ranking were water to cement ratios, acceptance inspection slump and mixing plan data. It seems that data related to their duties such as mixing plans and test results are rated as high degree importance items.

The items rated as low degree of importance were, as with all other groups, data on test results of materials used for concrete and data related to the people involved. Among the items of test results for materials used, the rating of mixture materials and admixtures was especially low. While the rating of data on bleeding at acceptance inspection was also low, this is assumed to be due to the fact that in general, bleeding inspection is rarely conducted and since the measurement takes time, the value of the data was judged as low.

(3) Trends of the responses from technicians engaged in operations related to concrete structure design/construction

Most of the technicians belonging to this group were technicians of general contractors (major construction contractors in Japan). Similar to the overall trend, past survey results as well as data on repair work and countermeasures, etc. were rated as having high degree of importance. As for concrete related information, data on strength was rated especially high. It was also observed that higher importance was placed on data on the building (post-completion data) than data on concrete properties or casting data.

As with all other groups, the items rated as low degree of importance were data on test results of materials used for concrete and data related to the people involved.

(4) Trends of the responses from technicians engaged in operations related to concrete structure in-service/maintenance management

Most of the technicians belonging to this group were technicians of construction consulting companies or governmental/public testing organizations, and many were certified concrete diagnosticians. The item rated especially high by this group was historical data of past repair work and countermeasures. Following this item in the rating, survey results and data for identifying the cause of faults (e.g., test results on materials used such as cement and chloride quantity, mixing plan data) were also rated as high degree importance items.

4.3 Specific items extracted as data of high degree importance

Among the items that ranked in the top 70 high degree importance items, those that are relatively readily storable are shown in **Table 4** and those that are difficult to store are shown in **Table 5**. While all items shown in these tables were rated as having high degree of importance, those shown in **Table 4** have fixed number of letters and since the data volume is small, it is possible that the data can be stored by current IC tag systems and other similar systems. On the other hand, storage of items shown in **Table 5** is difficult because of their large data volume. One of the future challenges is to develop new technologies for easy storage of these large sized data items so that these data can also be utilized.

5. Introduction of traceability system examples

5.1 Outline of trial experiments

Trial experiments were conducted at the site of aseismic renovation work at the Yoto Campus Building No.8 of Utsunomiya University. These trial experiments involved the following casting spots: floor expansion slabs, walls of the addition and the outdoor facility foundation. IC tags insertion experiment was implemented at floor expansion slabs and wall additions regarding "traceability system using IC tags", and concrete samples collection experiment was implemented regarding "management of concrete samples for strength tests using IC tags."

5.2 Traceability system using IC tags

The traceability system adopted for this trial experiment was developed as part of the joint research for the evaluation of technology for ensuring fresh concrete traceability using IC tags (FY2009 – FY2011) which was led by the National Institute for Land and Infrastructure Management. Specifically, it is a system mainly based on a basic application for accurately transmitting data between concrete manufacturers and contractors using IC tags[6)].

(1) IC tag utilization method

It is crucial that data are transmitted to the contractor while retaining the homogeneity of the product shipped from the fresh concrete production plant and the data showing its manufacturing process. However, fresh concrete is in a fluid state at the time of shipment, unloading, and casting. In order to unfailingly link the actual concrete placement parts after hardening and the particular production data, this system uses the method of inserting IC tags in concrete.

(2) Technical requirements for the traceability system

The system shown in **Fig. 6** was assumed for the transmission of fresh concrete production data to contractors. This system uses mixing plan values, measurements and related data which are prepared during the manufacturing process at the fresh concrete production plant as historical data. Because IC tags are inserted inside the fresh concrete, data are accessed by contact-free communication using a R/W at the concrete surface after casting has been completed.

(3) Application outline

The use of this application, as shown in **Fig. 7**, starts from transferring data on mixing plan values and measurements created by the fresh concrete production plant's production/shipment management system to the database built in the server, and saving the data. The ID of the IC tag is recovered using a portable R/W, and the data linked to the ID are extracted from the database. The result is displayed at the R/W screen and a computer screen. In addition, results of acceptance inspections and strength tests that are implemented during the distribution process of fresh concrete can be written onto the database through the IC tag at this point, thereby enhancing the fresh concrete historical data. The database is divided into two data tables regarding the mixing plan and printed record of measurements, and the ID is built with common data including the operation date, plan number and shipment sequence number.

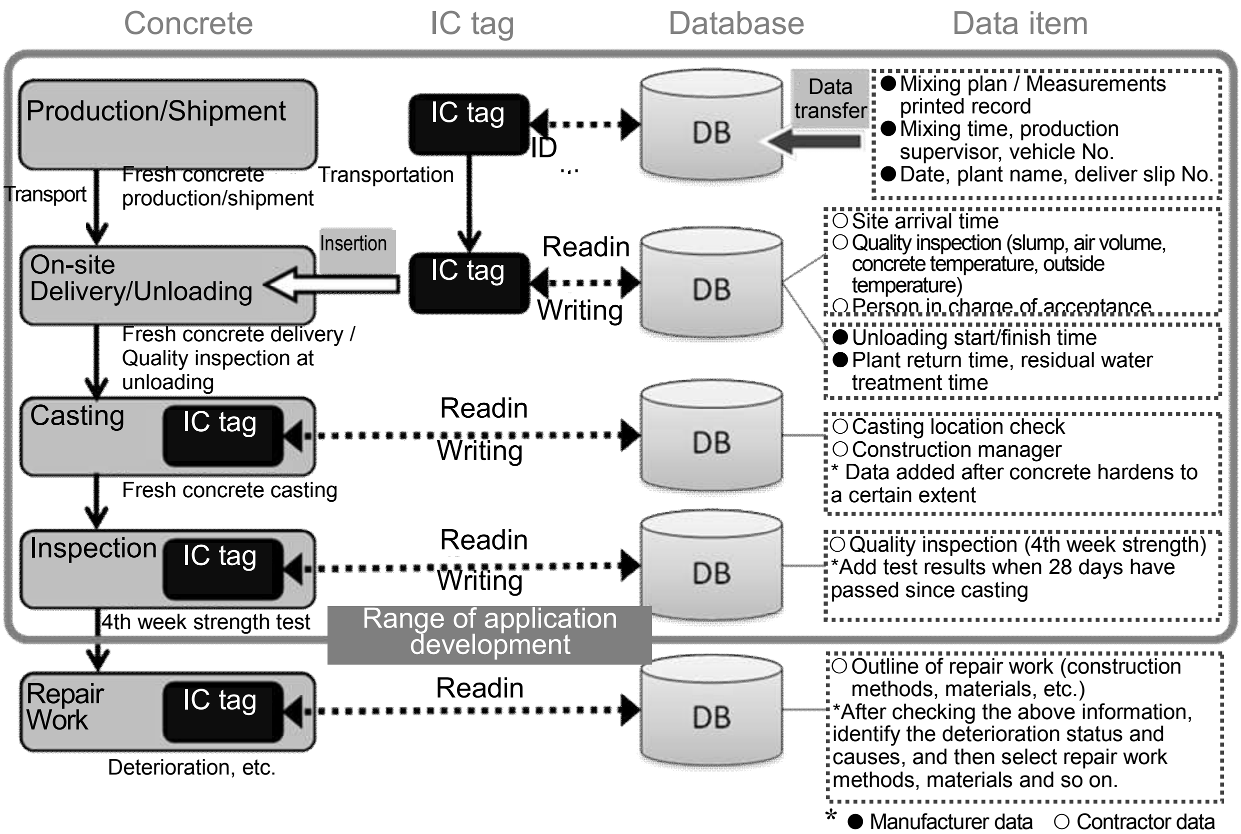

Fig. 6: Traceability system using IC tag[5)]

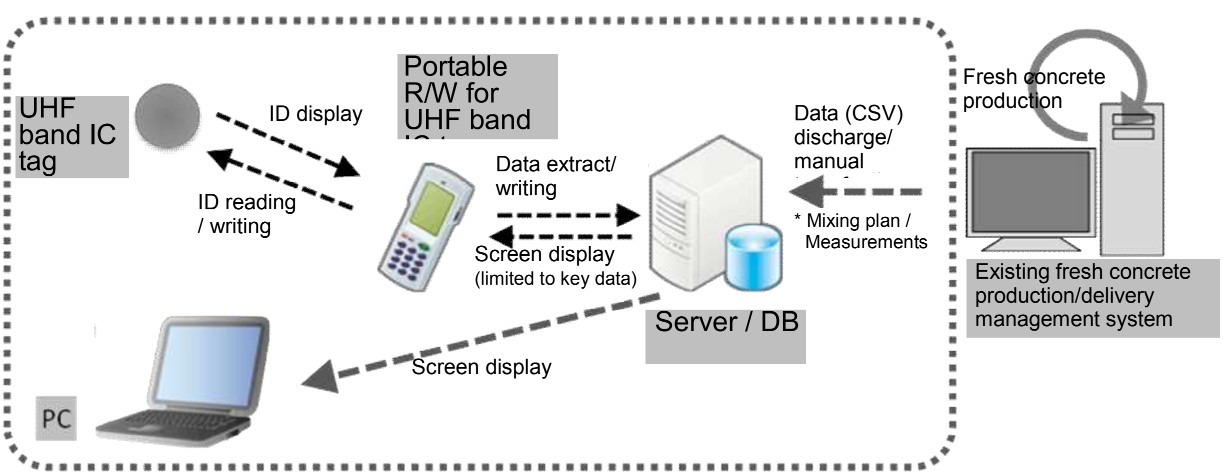

Fig. 7: Configuration of system and devices[5)]

5.3 Conditions of the IC tag insertion experiment at floor expansion slabs construction

The implementation conditions of IC tags insertion in concrete are presented in **Fig. 8**. IC tags were inserted at the inlet opening of the concrete pumping truck. After the concrete was casted, it was visually confirmed that IC tags had not floated up to the surface. The number of IC tags inserted into concrete ranged from 10 to 20 per one agitator vehicle. When communication was tested with the IC tags after the concrete hardened, communication was possible with roughly half of the IC tags. Further detailed researches will be conducted to obtain the precise probability of communication ability of IC tags inserted in concrete.

Furthermore, a traceability system trial using IC tags as described in **5.2** was conducted on-site, and along with the evaluation of its usefulness, future challenges were extracted.


1) Pouring concrete to pumping truck


2) Inserting IC tag


3) Pumping concrete

4) Concrete casting (distant view)

5) Concrete casting (close up view)

6) Concrete casting completed

Fig. 8: Experiment on IC tag insertion into concrete at expansion floor slabs construction

5.4 Management of concrete samples for strength tests using IC tags

This sample traceability system has been developed for the prevention of sample mix-ups and transcription errors by embedding data recorded IC tags into concrete samples for strength tests. In this experiment, ID tags were embedded in concrete samples collected during structure casting, and the effects were confirmed by using a sample software program.

For IC tag registration, default values are entered and IC tag identification number is registered. For default values, data regarding test name, casting date, test place, fresh concrete production plant, names of test observers are entered. Then, each IC tag planned to be embedded is entered by its reading identification number. In this experiment, as shown in **Fig. 9**, IC tags were embedded at a point 10mm from the side of the concrete sample (φ100×200mm) and 20mm below the top surface. By cross-checking the identification number of the IC tags embedded in the samples, each sample could be confirmed as the relevant sample from the tag ID, object name, etc., and the embedded IC tags enabled sample data management.

In addition to the tests presented here, a trial experiment of a traceability system using GPS and an experimental application of rebar-fixed IC tag were implemented. The details of these experiments are presented in the JCI committee report on Traceability System of Concrete [7] by the Japan Concrete Institute.

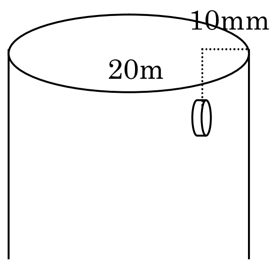

Fig. 9: Embedding an IC tag into a concrete sample

6. Conclusions and prospects

It is impossible for a single technician or organization to be involved in all the processes of the entire cycle from concrete production, casting, structure completion, in-service period to maintenance including repair/reinforcement work. Thus accurate information must be appropriately transferred between the involved parties, and the information must be stored by the owner or the manager of the structure. Regarding concrete structures, since the structures reach the ultimate functioning stage after going through a number of phases, it is important that traceability is ensured. Ensuring traceability has become increasingly important in the recent years for the following reasons:

(1) Companies are being extremely cautious against the occurrence of compliance failure regarding the entire society. In the field of concrete, whether or not the product was manufactured appropriately cannot be judged from the appearance of the hardened concrete in many cases, and once a problem occurs, concerns and feelings of distrust are hard to eliminate. In addition, faults become evident only after a considerable amount of time has passed, and the faults cause significant effects.

(2) As concrete structures age, the importance of their maintenance and extension of service life increases. Occasions for structure inspections and diagnoses, as well as implementation of reinforcement work as required are expected to rise. When making such maintenance plans, naturally, not only the structure inspection records but also data from the processes up until the completion of the structure are needed as well. Furthermore, in order to implement an efficient management of assets consisting of a group of multiple existing concrete structures, it is desirable that data is stored not only by paper-based methods, but to digitalize the data and then go a step further to build a database which can be mutually accessed by multiple management technicians.

(3) Based on the viewpoints of material resource conservation and environmental conservation, expectations are rising for effective utilization of recycled materials. Traceability becomes especially important when engaging in the effective utilization of recycled materials. Concrete structures could be dismantled after serving their role and may be included in the process of recycling project as recycled aggregates and roadbed material. A traceability system can be used for transmitting appropriate data to organizations involved in recycling projects, and for ensuring the reliability of the quality of the recycled material.

As described so far, it is critical that concrete traceability is ensured. In order to ensure traceability without being heavily burdened, regarding the data on structure construction and maintenance, it is important to narrow down the information for storage according to its degree of importance, to improve the searchability of the required data, and to ultimately create laborsaving data storage systems. It is expected that labor required for data collection and storage is further reduced by skillfully using technologies of the IT field such as IC tags and GPS.

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