

DESCRIPTION

Title of Invention

PREPARATION ESTIMATING METHOD AND PREPARATION
5 ESTIMATING DEVICE

Technical Field

[0001] The present invention relates to a preparation estimating method and a preparation estimating device for fresh concrete.

Background Art

10 [0002] For example, fresh concrete is transported to a construction site, and work for estimating preparation of fresh concrete has been conventionally performed on the transported fresh concrete. This work is important for estimating the strength of concrete and controlling the quality of the concrete. As a method for estimating the preparation of
15 fresh concrete, Japanese Unexamined Patent Publication No. H2-276965 describes a measurement method for determining the ratio of water to cement contained in fresh concrete.

[0003] In this measurement method, mortar is collected from fresh concrete, a cement component contained in the collected mortar is
20 dissolved in ion exchange resin, and the electric conductivity of filtrate obtained by dissolving is measured. Then, the cement amount is measured from the measured electric conductivity, the collected mortar is dried, and the water content of the fresh concrete is measured from the degree of weight loss when the collected mortar is dried. Thus, the
25 cement amount and the water amount are measured, and the ratio of water to cement is determined from the measurement results.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Publication No. H2-276965

5 Summary of Invention

Technical Problem

[0005] In the measurement method described above, the ratio of water to cement is determined through dissolution of the cement component by the ion exchange resin, drying of the mortar, and the like. As described above, since the measurement method described above involves dissolution by the ion exchange resin, drying of the mortar and the like, it takes a long time for the measurement, and there is a problem that the preparation of the fresh concrete cannot be quickly evaluated at the site.

15 [0006] Further, the estimation of the preparation of fresh concrete is performed at the site where the fresh concrete has been transported, and there is a case where it is necessary to determine whether or not to purchase fresh concrete using the result of the estimation of the preparation. As described above, there is a case where it is necessary to make a determination at the site, and therefore, it is required to estimate the preparation in a short time. However, the measurement method described above requires a great deal of time through drying and the like, and is not suitable for use at the site. Therefore, a method for quickly estimating the preparation of fresh concrete is required.

25 [0007] An object of the present invention is to provide a preparation estimating method and a preparation estimating device which can

quickly estimate preparation of fresh concrete.

Solution to Problem

[0008] The present inventors have found that the electric conductivity of fresh concrete is affected by the components and temperature of fresh concrete. According to this finding, the components of fresh concrete can be estimated in a short time by measuring the electric conductivity, temperature, and mass per unit volume (unit volume mass) of fresh concrete. The present invention has been made based on such a finding. That is, according to the present invention, there is provided a preparation estimating method for estimating preparation of fresh concrete containing water, cement, and aggregate. The preparation estimating method includes: a step of measuring electric conductivity of the fresh concrete; a step of measuring temperature of the fresh concrete; a step of measuring mass per unit volume of the fresh concrete; and a step of calculating a water amount of water contained in the fresh concrete, a cement amount of cement contained in the fresh concrete, and an aggregate amount of aggregate contained in the fresh concrete from the electric conductivity, the temperature, and the mass per unit volume.

[0009] In the preparation estimating method, the electric conductivity, the temperature, and the unit volume mass of the fresh concrete are measured, and the water amount of water, the cement amount, and the aggregate amount contained in the fresh concrete are calculated from the electric conductivity, the temperature, and the unit volume mass which are thus measured. As described above, since the water amount, the cement amount, and the aggregate amount are calculated from the

electric conductivity, the temperature, and the unit volume mass, the amounts of water and cement, and the aggregate amount contained in the fresh concrete can be quickly and easily derived. If the water amount and the cement amount are known, the water-cement ratio can be grasped. As a result, the strength of the fresh concrete can be easily estimated from the water-cement ratio. Specifically, when the ratio of water to cement is high, it can be estimated that the strength of the fresh concrete is low. As described above, the preparation and strength of the fresh concrete can be quickly estimated, so that the quality of the fresh concrete can be efficiently evaluated.

[0010] In addition, the fresh concrete may contain admixture. The preparation estimating method described above may include: a step of measuring density of each of the water, the cement, the aggregate, and the admixture contained in the fresh concrete; and a step of measuring an air amount contained in the fresh concrete. In the calculating step described above, the water amount, the cement amount, the aggregate amount, and an admixture amount of the admixture contained in the fresh concrete may be calculated from the electric conductivity, the temperature, the unit volume mass, the density, and the air amount. In this case, the amount of the admixture can be quickly and easily derived. Further, the strength of the fresh concrete can be estimated from the admixture amount, the water amount, and the cement amount.

[0011] In the step of measuring the density, the density may be calculated in advance before the calculating step is performed. In this case, even when the densities of the water, the cement, the aggregate, and the admixture are unknown, by calculating the densities in advance,

the amounts of the water, the cement, the aggregate, and the admixture contained in the fresh concrete can be calculated quickly. Therefore, the preparation of the fresh concrete can be estimated more quickly.

[0012] In the step of measuring the air amount, the air amount may be calculated in advance before the calculating step is performed. In this case, even when there is no measuring device configured to measure the air amount at the site, the preparation of the fresh concrete can be quickly estimated by calculating the air amount in advance. Further, by calculating the air amount in advance, it is not necessary to measure the air amount at the site, so that the preparation of the fresh concrete can be estimated more quickly.

[0013] According to the present invention, there is provided a preparation estimating device configured to estimate preparation of fresh concrete containing water, cement, and aggregate. The preparation estimating device includes: an electric conductivity measuring unit configured to measure electric conductivity of the fresh concrete; a temperature measuring unit configured to measure temperature of the fresh concrete; a unit volume mass measuring unit configured to measure mass per unit volume of the fresh concrete; and a calculating unit configured to calculate a water amount of water contained in the fresh concrete, a cement amount of cement contained in the fresh concrete, and an aggregate amount of aggregate contained in the fresh concrete from the electric conductivity, the temperature, and the mass per unit volume.

[0014] In the preparation estimating device, the electric conductivity measuring unit measures the electric conductivity of the fresh concrete,

the temperature measuring unit measures the temperature of the fresh concrete, and the unit volume mass measuring unit measures the unit volume mass of the fresh concrete. The calculating unit calculates the water amount, the cement amount, and the aggregate amount from the electric conductivity, the temperature, and the unit volume mass. The calculating unit calculates the water amount, the cement amount, and the aggregate amount from the electric conductivity, the temperature, and the unit volume mass, so that the water amount, the cement amount, and the aggregate amount of the fresh concrete can be quickly and easily derived. Therefore, similarly to the preparation estimating method described above, the preparation of the fresh concrete can be quickly estimated, and the quality of the fresh concrete can be efficiently evaluated.

Advantageous Effects of Invention

[0015] According to the present invention, the preparation of the fresh concrete can be estimated quickly.

Brief Description of Drawings

[0016] FIG. 1 is a block diagram showing a preparation estimating device for fresh concrete according to an embodiment.

FIG. 2 is a perspective view showing an example of a measuring unit for fresh concrete in the preparation estimating device of FIG. 1.

FIG. 3 is a graph showing a relationship between a unit volume mass and an air ratio of fresh concrete.

FIG. 4 is a diagram showing an example of a display unit of the preparation estimating device of FIG. 1.

FIG. 5(a) is a graph showing a relationship between a measured

value of electric resistivity ($1/EC$) of fresh concrete and a calculated value of electric resistivity ($1/EC$) by a regression expression. FIG. 5(b) is a graph showing a relationship between an admixture amount of the fresh concrete and $\Delta (1/EC)$.

FIG. 6(a) is a graph showing a relationship between a measured value of $\ln EC$ and a calculated value of $\ln EC$ obtained by a regression expression. FIG. 6(b) is a graph showing a relationship between the admixture amount and $\Delta (\ln EC)$.

FIG. 7(a) is a graph showing a relationship between a cement amount and $\Delta (1/EC)$ for each type of cement. FIG. 7(b) is a graph showing a relationship between a cement amount and $\Delta (\ln EC)$ for each type of cement.

FIG. 8(a) is a graph showing a relationship between a cement amount and $\Delta (1/EC)$ for each type of cement. FIG. 8(b) is a graph showing a relationship between a cement amount and $\Delta (\ln EC)$ for each type of cement.

FIGS. 9(a) and 9(b) are graphs showing a relationship between actual preparation and estimated preparation.

FIGS. 10(a) and 10(b) are graphs showing a relationship between actual preparation and estimated preparation.

FIG. 11 is a flowchart showing a preparation estimating method for fresh concrete according to the embodiment.

Description of Embodiments

[0017] Hereinafter, a preparation estimating device and a preparation estimating method for fresh concrete according to an embodiment will be described with reference to the drawings. In description of the

drawings, the same or corresponding elements are denoted by the same reference numerals, and redundant description is omitted as appropriate.

[0018] First, the preparation estimating device for fresh concrete according to the present embodiment will be described. FIG. 1 is a

5 block diagram showing a preparation estimating device 1 according to the present embodiment. FIG. 2 is a perspective view showing an example of means for measuring a fresh concrete R. The fresh

concrete R is ready-mixed concrete that is transported to a construction site, and is unloaded in a non-solidified state. After the fresh concrete

10 R is solidified, it takes a lot of time to repair or remove it. Thus, it is important to perform a quality inspection before the fresh concrete R is solidified. The preparation estimating device 1 performs a quality

inspection on the fresh concrete R carried into the construction site, and inspects whether or not the preparation of the fresh concrete R is in a

15 desired state.

[0019] The fresh concrete R contains, for example, ordinary portland cement. The fresh concrete R is composed of water, aggregate including fine aggregate and coarse aggregate, cement, and admixture.

The admixture may contain fly ash, blast furnace slag, and the like.

20 The admixtures such as fly ash and blast furnace slag are used to increase the strength by reacting with the cement. That is, the cement and the admixture are binders configured to increase the strength of the fresh concrete R.

[0020] The preparation estimating device 1 estimates the preparation of the fresh concrete R before the fresh concrete R is purchased, for example. As described above, the preparation of the fresh concrete R

is estimated by the preparation estimating device 1 before the purchase, so that a purchaser can quickly determine whether or not to purchase the fresh concrete R at the site.

[0021] As shown in FIG. 1, the preparation estimating device 1 includes an electric conductivity measuring unit 11 configured to measure the electric conductivity of the fresh concrete R, a temperature measuring unit 12 configured to measure the temperature of the fresh concrete R, a unit volume mass measuring unit 13 configured to measure the unit volume mass (mass per unit volume) of the fresh concrete R, a density measuring unit 14 configured to measure the density of each component of the fresh concrete R, and an air amount measuring unit 15 configured to measure the amount of air contained in the fresh concrete R. In this disclosure, density of concrete may be called unit volume mass (mass per unit volume).

[0022] Further, the preparation estimating device 1 includes a calculating unit 20 configured to calculate the amount of each component of the fresh concrete R, and a display unit 30 configured to display each component calculated by the calculating unit 20. The measurement values measured by the electric conductivity measuring unit 11, the temperature measuring unit 12, the unit volume mass measuring unit 13, the density measuring unit 14, and the air amount measuring unit 15 are input to the calculating unit 20. The calculating unit 20 calculates a water amount W, an aggregate amount G, a cement amount C, and an admixture amount F, which are components of the fresh concrete R, from the input measured values. The calculating unit 20 and the display unit 30 may be included in a mobile terminal such as

a tablet terminal, for example. In this case, the input of each measurement value to the calculating unit 20 and the display of the calculated amount of each component are performed on the display of the tablet terminal.

5 [0023] For example, as shown in FIG. 2, the electric conductivity measuring unit 11 includes an electric conductivity cell 11a inserted into the fresh concrete R. The electric conductivity of the fresh concrete R is measured by inserting the electric conductivity cell 11a into the fresh concrete R. The electric conductivity measured by the electric conductivity measuring unit 11 is input to the calculating unit 20. The electric conductivity cell 11a is inserted into, for example, each of the four freely-selected portions P1, P2, P3, and P4, and the measured four electric conductivities are input to the calculating unit 20. Note that the configuration of the electric conductivity measuring unit 11 and the portions where the electric conductivity cell 11a is inserted are not limited to the above example and may be changed as appropriate.

15 [0024] The temperature measuring unit 12 includes, for example, a sensor unit inserted into the fresh concrete R similarly to the electric conductivity cell 11a, and measures the temperature of the fresh concrete R by inserting the sensor unit into the fresh concrete R. The temperature of the fresh concrete R measured by the temperature measuring unit 12 is input to the calculating unit 20. Note that the configuration of the temperature measuring unit 12 may also be changed as appropriate.

20 [0025] The unit volume mass measuring unit 13 performs measurement, for example, by determining the mass of the fresh concrete R filled in a

container having a predetermined capacity. In addition, prior to the measurement of the fresh concrete R at the site, the unit volume mass may be measured by kneading and mixing a plurality of types (N types) of concrete for preparation in a laboratory or a concrete plant. The unit volume mass of the fresh concrete R measured by the unit volume mass measuring unit 13 is input to the calculating unit 20. The configuration of the unit volume mass measuring unit 13 may also be changed as appropriate.

[0026] The density measuring unit 14 measures the density of each of water, cement, aggregate, and admixture contained in the fresh concrete R. Each density measured by the density measuring unit 14 is input to the calculating unit 20. The density measuring unit 14 may measure each density above in advance before measurement at the site. As a specific example, the density measuring unit 14 calculates the densities of cement, aggregate, and admixture as the reciprocals of b1, b2, and b3 using Expression (1).

[Expression 1]

$$\begin{bmatrix} \sum x_{1j}^2 & \sum x_{1j}x_{2j} & \sum x_{1j}x_{3j} \\ \sum x_{1j}x_{2j} & \sum x_{2j}^2 & \sum x_{2j}x_{3j} \\ \sum x_{1j}x_{3j} & \sum x_{2j}x_{3j} & \sum x_{3j}^2 \end{bmatrix} \begin{Bmatrix} b_1 \\ b_2 \\ b_3 \end{Bmatrix} = \begin{bmatrix} \sum x_{1j}y_j \\ \sum x_{2j}y_j \\ \sum x_{3j}y_j \end{bmatrix} \quad \cdot \cdot \cdot (1)$$

[0027] x_{1j} , x_{2j} , x_{3j} ($j = 1, 2, \dots, N$) are the masses of cement, aggregate, and admixture in a preparation j, and y_j is the volume of the solid material. Here, assuming that the reciprocal of the calculated density is b_i , the calculated value y_j' of the volume of the solid material is represented by Expression (2).

[Expression 2]

$$y_j' = b_1 x_{1j} + b_2 x_{2j} + b_3 x_{3j} \quad \cdot \cdot \cdot (2)$$

The expression for determining b_1 , b_2 , and b_3 by the least squares method for the N preparations ($j = 1, 2, \dots, N$) is Expression (1) described above. Specifically, Expression (1) is a simultaneous equation that satisfies Expression (4) with respect to Expression (3).

[Expression 3]

$$Q = \sum (y_j - y_j')^2 \quad \cdot \cdot \cdot (3)$$

[Expression 4]

$$\frac{\partial Q}{\partial b_0} = 0, \frac{\partial Q}{\partial b_1} = 0, \frac{\partial Q}{\partial b_2} = 0, \frac{\partial Q}{\partial b_3} = 0 \quad \cdot \cdot \cdot (4)$$

[0028] The air amount measuring unit 15 measures the amount of air (air amount) contained in the fresh concrete R. The air amount measured by the air amount measuring unit 15 is input to the calculating unit 20. The air amount measuring unit 15 may measure the air amount according to, for example, JIS A 1128 (test method based on the pressure of the air amount of fresh concrete). Further, the air amount measuring unit 15 may measure the air ratio A of the fresh concrete R from the unit volume mass UW (kg/m^3) determined by the unit volume mass measuring unit 13 using Expression (5).

[Expression 5]

$$A = a_0 + a_1 UW \quad \cdot \cdot \cdot (5)$$

[0029] From the unit volume mass UW_j (kg/m^3) of the preparation j (x_{1j} , x_{2j} , x_{3j} , x_{4j} : kg) ($j = 1, 2, \dots, N$), each preparation amount x_{ij} (kg/m^3) in 1 m^3 may be calculated as in Expression (6) to determine the air ratio A_j .

[Expression 6]

$$w_j = \sum_i x_{ij} \quad x_{ij} = \frac{UW}{w_j} x_{ij} \quad A_j = 1 - \sum_i \frac{x_{ij}}{\rho_i} \quad \cdot \cdot \cdot (6)$$

[0030] Expression (5) is a regression expression from N (A_j, UW_j) in Expression (6). In addition, it is known that the relationship between the air ratio A contained in the fresh concrete R and the unit volume mass UW is represented by a relationship of a linear function as shown in FIG. 3. Therefore, the air amount measuring unit 15 may determine the air ratio A of the fresh concrete R from the unit volume mass UW measured by the unit volume mass measuring unit 13, and calculate the air amount V_a from the determined air ratio A.

[0031] The display unit 30 displays each component of the fresh concrete R calculated by the calculating unit 20. For example, as shown in FIG. 4, the display unit 30 includes a display 31. The display 31 is provided with text boxes 31a, 31b, 31c, 31d, 31e, 31f, 31g, and 31h configured to display the temperature, water amount, electric conductivity, unit volume mass, cement amount, aggregate amount, admixture amount, and pass/fail (whether or not the preparation of the fresh concrete R is in a desired state) of the fresh concrete R, respectively.

[0032] To the calculating unit 20, the electric conductivity of the fresh concrete R, the temperature of the fresh concrete R, the unit volume mass of the fresh concrete R, the density of each component (water, cement, aggregate, and admixture) of the fresh concrete R, and the air amount of the fresh concrete R are input. As shown in FIG. 1, the calculating unit 20 includes a water amount calculating unit 21, an aggregate amount calculating unit 22, a cement amount calculating unit

23, and an admixture amount calculating unit 24. The calculating unit 20 is, for example, a tablet terminal as described above, and includes, for example, a central processing unit (CPU) and a storage unit including a read only memory (ROM) and a random access memory (RAM). Each function of the calculating unit 20 is realized, for example, by loading a program stored in the ROM into the RAM and executing it by the CPU.

[0033] The storage unit of the calculating unit 20 stores, for example, Expressions (7) to (10) described below.

[Expression 7]

$$1/EC = a_0 + a_1(1/T) + a_2W + a_3C + a_4G + a_5F \quad \cdot \cdot \cdot (7)$$

(1/EC) is the electric resistivity of the fresh concrete R, T is the temperature (K) of the fresh concrete R, W is the water amount in the fresh concrete R (kg/m³), C is the cement amount (kg/m³) in the fresh concrete R, G is the aggregate amount (kg/m³) of the fresh concrete R, and F is the admixture amount (kg/m³) of the fresh concrete R. The electric resistivity (1/EC) is the reciprocal of the electric conductivity EC. a₀, a₁, a₂, a₃, a₄, and a₅ indicate coefficients determined in advance by regression analysis for each type of the fresh concrete R.

[0034]

[Expression 8]

$$\ln EC = b_0 + b_1(1/T) + b_2W + b_3C + b_4G + b_5F \quad \cdot \cdot \cdot (8)$$

lnEC indicates the logarithm of EC, and b₀, b₁, b₂, b₃, b₄, and b₅ indicate coefficients determined in advance by regression analysis for each type of the fresh concrete R.

[0035]

[Expression 9]

$$UW = W + C + G + F \quad \cdot \cdot \cdot (9)$$

Expression (9) indicates that the unit volume mass UW (kg/m³) of the fresh concrete and the sum of the masses of the components are equal to each other.

[Expression 10]

$$1 = W/\rho_w + C/\rho_c + G/\rho_g + F/\rho_f + V_a \quad \cdot \cdot \cdot (10)$$

ρ_w indicates the density of water, ρ_c indicates the density of cement, ρ_g indicates the density of aggregate, ρ_f indicates the density of admixture, and V_a indicates the air amount. Expression (10) indicates that the sum of the values obtained by dividing the mass of each component by the density of each component is 1.

[0036] For example, from Expressions (7) to (10) described above, the water amount calculating unit 21 calculates the water amount W of the fresh concrete R, the aggregate amount calculating unit 22 calculates the aggregate amount G of the fresh concrete R, the cement amount calculating unit 23 calculates the cement amount C of the fresh concrete R, and the admixture amount calculating unit 24 calculates the admixture amount F of the fresh concrete R.

[0037] For example, when the fresh concrete R is ordinary portland cement, values of $a_0, a_1, a_2, a_3, a_4, a_5, b_0, b_1, b_2, b_3, b_4$, and b_5 are $a_0 = -0.869, a_1 = 188, a_2 = -7.84 \times 10^{-4}, a_3 = -1.39 \times 10^{-4}, a_4 = 2.79 \times 10^{-4}, a_5 = 4.37 \times 10^{-4}, b_0 = 17.3, b_1 = -2.70 \times 10^3, b_2 = 1.01 \times 10^{-2}, b_3 = 1.14 \times 10^{-3}, b_4 = -4.42 \times 10^{-3}$, and $b_5 = -3.92 \times 10^{-3}$, respectively. However, the values of $a_0, a_1, a_2, a_3, a_4, a_5, b_0, b_1, b_2, b_3, b_4$, and b_5 are changed according to the type of the fresh concrete R.

[0038] The basis for deriving Expression (7) described above will be described. Expression (7) is an expression indicating the electric resistivity ($1/EC$). The empirical rule that the total resistance when there are several scattering mechanisms that cause scattering of the electric resistivity ($1/EC$) is the sum of the resistances when each mechanism exists alone is known as the Mathiesen's law. For example, it has been found that the electric resistivity of a dilute alloy is the sum of a temperature-independent resistance (derived from impurity scattering) and a temperature-dependent resistance (derived from lattice scattering). In general, since the electric resistivity of a substance depends on the temperature, the electric resistivity ($1/EC$) of the fresh concrete R is expressed as Expression (7) including the temperature-dependent term and the term of each material with reference to the Mathiesen's law.

[0039] In addition, Expression (11) is obtained as a result of multiple regression analysis on 46 actually measured data pieces obtained from the fresh concrete containing the water amount W, the cement amount C when the concrete is ordinary portland cement, and the aggregate amount G. In Expression (11), the admixture amount F (the amount of fly ash FA) is set to 0. The value calculated by the regression expression of Expression (11) is in good agreement with the measured value as shown in FIG. 5(a). Thus, the validity of Expression (11) is verified.

[Expression 11]

$$1/EC \approx f(T, W, C, G) = a'_0 + a_1(1/T) + a_2W + a_3C + a_4G \quad \cdot \cdot \cdot (11)$$

In Expression (11), $a'_0 = -0.869$, $a_1 = 188$, $a_2 = -7.84 \times 10^{-4}$, $a_3 =$

-1.39 × 10⁻⁴, and a₄ = 2.79 × 10⁻⁴.

[0040] Next, Δ (1/EC) is determined, which is a difference between the measured value of the electric resistivity (1/EC) of each of 22 actually measured data pieces obtained from the fresh concrete containing the water amount W, the cement amount C, the aggregate amount G, and the admixture amount F (fly ash FA) and the calculated value obtained by substituting the water amount W, the cement amount C, and the aggregate amount G into Expression (11). As a result, a linear relationship shown in FIG. 5(b) and Expression (12) is confirmed between Δ (1/EC) and the admixture amount F.

[Expression 12]

$$\Delta(1/EC) = 1/EC - f(T, W, C, G) = a_0'' + a_5 F \quad \cdot \cdot \cdot (12)$$

In Expression (12), a₀'' = 0 and a₅ = 4.37 × 10⁻⁴.

[0041] From the above results, the electric resistivity (1/EC) is expressed by the sum of Expressions (11) and (12) and Expression (13).

[Expression 13]

$$\begin{aligned} 1/EC &= f(T, W, C, G) + \Delta(1/EC) = \left(a_0' + a_0'' \right) + a_1(1/T) + a_2W + a_3C + a_4G + a_5F \\ &= a_0 + a_1(1/T) + a_2W + a_3C + a_4G + a_5F \\ &\quad \cdot \cdot \cdot (13) \end{aligned}$$

In Expression (13), a₀ = -0.869, a₁ = 188, a₂ = -7.84 × 10⁻⁴, a₃ = -1.39 × 10⁻⁴, a₄ = 2.79 × 10⁻⁴, and a₅ = 4.37 × 10⁻⁴.

Expression (7) is derived from Expression (13) above.

[0042] The basis for deriving Expression (8) described above will be described. The electric conductivity EC of the fresh concrete is governed by the ion mobility of the cement aqueous solution. According to this assumption, the electric conductivity EC can be

expressed by Expression (14), and it is considered that Expression (15), which is Einstein's relational expression, holds.

[Expression 14]

$$EC = ne\mu \quad \cdot \cdot \cdot (14)$$

5 [Expression 15]

$$\mu = eD/k_B T \quad \cdot \cdot \cdot (15)$$

[0043] In Expressions (14) and (15), n is the number of ions in a unit volume, e is the charge of the ions, μ is the mobility of the ions, T is the absolute temperature, D is the diffusion coefficient, and k_B is the Boltzmann constant. Further, the diffusion coefficient D has a temperature dependency as in Expression (16).

10

[Expression 16]

$$D = D_0 \exp\left(-\frac{Q}{RT}\right) \quad \cdot \cdot \cdot (16)$$

[0044] In Expression (16), Q represents the activation energy of diffusion, R represents a gas constant, and D_0 represents a constant (frequency factor). Expression (17) is derived from Expressions (14) to (16).

15

[Expression 17]

$$EC = \frac{ne^2}{k_B T} D_0 \exp\left(-\frac{Q}{RT}\right) \quad \cdot \cdot \cdot (17)$$

[0045] Taking the logarithm of Expression (17), the following expression is obtained.

20

[Expression 18]

$$\ln EC = \ln\left(\frac{ne^2 D_0}{k_B}\right) + \ln\frac{1}{T} - \frac{Q}{RT} \quad \cdot \cdot \cdot (18)$$

[0046] Further, when Expression (19) indicating the Taylor series expansion is applied to the two terms on the right side of Expression (18) and approximated by Expression (20), Expression (21) is obtained.

[Expression 19]

$$5 \quad \ln x = \ln x_0 \left(1 + \frac{\Delta x}{x_0} \right) \approx \ln x_0 + \frac{\Delta x}{x_0} = \ln x_0 + \frac{x}{x_0} - 1 = c_0 + c_1 x \quad \cdot \cdot \cdot (19)$$

[Expression 20]

$$\ln 1/T \approx c_0 + c_1 \frac{1}{T} \quad \cdot \cdot \cdot (20)$$

[Expression 21]

$$\ln EC = A + B \frac{1}{T} \quad \cdot \cdot \cdot (21)$$

10 [0047] Since it is considered that A described above consisting of the ion concentration, the frequency factor of diffusion, and the constant depends on the preparation, Expression (22) is assumed which is obtained by replacement to a linear expression of each preparation amount.

15 [Expression 22]

$$\ln EC = b_0 + b_1(1/T) + b_2W + b_3C + b_4G + b_5F \quad \cdot \cdot \cdot (22)$$

[0048] In addition, an Expression (23) is obtained as a result of multiple regression analysis on 46 actually measured data pieces of the fresh concrete containing the water amount W, the cement amount C, and the aggregate amount G used for deriving Expression (7). The calculated value by the regression expression of Expression (23) and the measured value of lnEC show good agreement as shown in FIG. 6(a). Thus, the validity of Expression (22) is verified.

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[Expression 23]

$$\ln EC \approx g(T, W, C, G) = b_0' + b_1(1/T) + b_2W + b_3C + b_4G \quad \cdot \cdot \cdot (23)$$

In Expression (23), $b_0' = 17.4$, $b_1 = -2.70 \times 10^3$, $b_2 = 1.01 \times 10^{-2}$, $b_3 = 1.14 \times 10^{-3}$, and $b_4 = -4.42 \times 10^{-3}$.

5 [0049] Next, a linear relationship shown in FIG. 6(b) and Expression (24) is confirmed in the admixture amount F and $\Delta(\ln EC)$ which is a difference between the measured value of $\ln EC$ of each of 22 actually measured data pieces obtained from the fresh concrete containing the water amount W, the cement amount C, the aggregate amount G, and
10 the admixture amount F used for deriving Expression (7) and the calculated value obtained by substituting the water amount W, the cement amount C, and the aggregate amount G into Expression (23).

[Expression 24]

$$\Delta(\ln EC) = \ln EC - g(T, W, C, G) = b_0'' + b_5F \quad \cdot \cdot \cdot (24)$$

15 In Expression (24), $b_0'' = -1.39 \times 10^{-1}$ and $b_5 = 3.92 \times 10^{-4}$.

[0050] As described above, $\ln EC$ is represented by the sum of Expressions (23) and (24), and Expression (25).

[Expression 25]

$$\begin{aligned} \ln EC &= g(T, W, C, G) + \Delta(\ln EC) = \left(b_0' + b_0'' \right) + b_1(1/T) + b_2W + b_3C + b_4G + b_5F \\ &= b_0 + b_1(1/T) + b_2W + b_3C + b_4G + b_5F \end{aligned}$$

20 $\cdot \cdot \cdot (25)$

In Expression (25), $b_0 = 17.3$, $b_1 = -2.70 \times 10^3$, $b_2 = 1.01 \times 10^{-2}$, $b_3 = 1.14 \times 10^{-3}$, $b_4 = -4.42 \times 10^{-3}$, and $b_5 = -3.92 \times 10^{-3}$.

Expression (8) is derived from Expression (25) above.

[0051] Expressions (7) and (8) described above are modified according
25 to the type of the fresh concrete cement. Hereinafter, the modification

of Expressions (7) and (8) according to the type of cement will be described. The values of the coefficients $a_0, a_1, a_2, a_3, a_4, a_5, b_0, b_1, b_2, b_3, b_4,$ and b_5 in Expressions (13) and (25) are values when ordinary portland cement is used. If the cement is not ordinary portland cement, the values of the above coefficients and constant terms are modified. It is experimentally confirmed that the difference between the calculated value and the measured value according to Expressions (13) and (25) can be approximated by a linear expression of the unit cement amount as in Expressions (26) and (27).

[Expression 26]

$$\Delta(1/EC) = \text{value of expression (13)} - 1/\text{measured value of EC} \\ \approx c_0 + c_3 C \quad \cdot \cdot \cdot (26)$$

[Expression 27]

$$\Delta(\ln EC) = \text{value of expression (25)} - 1/\text{measured value of EC} \\ \approx d_0 + d_3 C \quad \cdot \cdot \cdot (27)$$

In Expressions (26) and (27), $c_0, c_3, d_0,$ and d_3 are constants.

[0052] The values of the above constants $c_0, c_3, d_0,$ and d_3 may be determined from several types of preparations, and may be modified as in Expressions (28) and (29).

[Expression 28]

$$1/EC = \text{value of expression (13)} - (c_0 + c_3 C) \quad \cdot \cdot \cdot (28)$$

[Expression 29]

$$\ln EC = \text{value of expression (25)} - (d_0 + d_3 C) \quad \cdot \cdot \cdot (29)$$

[0053] The relationship between the cement amount C and $\Delta(1/EC)$, and the relationship between the cement amount C and $\Delta(\ln EC)$ are shown in FIG. 7(a), FIG. 7(b), FIG. 8(a), and FIG. 8(b). As shown in

FIG. 7(a), FIG. 7(b), FIG. 8(a), and FIG. 8(b), it can be seen that both of the relationship between the cement amount C and $\Delta (1/EC)$ and the relationship between the cement amount C and $\Delta (\ln EC)$ satisfy the linear relationship. That is, y ($\Delta (1/EC)$ or $\Delta (\ln EC)$) is represented by a linear function of x (cement amount C). Note that NP_P, NS_S, TS_R, and TC_L in the graphs indicate the types of cement, respectively. Also, y indicates the correction amount.

[0054] In addition, the relationship between the estimated preparation of the water amount W , the cement amount C , the aggregate amount G , and the admixture amount F (fly ash) obtained using Expressions (7) to (10), and the actual preparation which is the preparation actually obtained are shown in FIG. 9(a), FIG. 9(b), FIG. 10(a) and FIG. 10(b). As shown in FIG. 9(a), FIG. 9(b), FIG. 10(a), and FIG. 10(b), it can be seen that the estimated preparation of each component using Expressions (7) to (10) and actual preparation are substantially in agreement with each other. Thus, the validity of Expressions (7) to (10) is verified.

[0055] In Expression (7) indicating the electric resistivity ($1/EC$), the coefficient a_1 of the reciprocal of the temperature T is positive, the coefficient a_2 of the water amount W is negative, the coefficient a_3 of the cement amount C is negative, the coefficient a_4 of the aggregate amount G is positive, and the coefficient a_5 of the admixture amount F is positive. This is based on the finding that the electric resistivity ($1/EC$) decreases when the temperature T increases or the water amount W or the cement amount C increases, and the electric resistivity ($1/EC$) increases when the aggregate amount G or the admixture amount F

increases.

[0056] In Expression (8) indicating $\ln EC$ which is the logarithm of the electric conductivity, the coefficient b_1 of the reciprocal of the temperature T is negative, the coefficient b_2 of the water amount W is positive, the coefficient b_3 of the cement amount C is positive, the coefficient b_4 of the aggregate amount G is negative, and the coefficient b_5 of the admixture amount F is negative. This is based on the finding that the electric conductivity EC increases when the temperature T increases or the water amount W or the cement amount C increases, and the electric conductivity EC decreases when the aggregate amount G or the admixture amount F increases.

[0057] Next, a preparation estimating method for the fresh concrete R according to the present embodiment will be described. FIG. 11 is a flowchart showing an example of a preparation estimating method using the preparation estimating device 1. First, the electric conductivity EC , the temperature T , and the unit volume mass UW of the fresh concrete R are measured using the electric conductivity measuring unit 11, the temperature measuring unit 12, and the unit volume mass measuring unit 13 (Step S1).

[0058] Specifically, the electric conductivity EC is measured by inserting the electric conductivity cell 11a into the fresh concrete R , and the measured electric conductivity EC is input to the calculating unit 20. Then, the sensor unit of the temperature measuring unit 12 is inserted into the fresh concrete R to measure the temperature T , and the measured temperature T is input to the calculating unit 20 (step of inputting the electric conductivity and the temperature). Further, for

example, the unit volume mass measuring unit 13 measures the unit volume mass UW by determining the mass of the fresh concrete R filled in a container having a predetermined capacity, and inputs the measured unit volume mass UW to the calculating unit 20 (step of inputting unit volume mass).

[0059] Subsequently, the density ρ_W of water of the fresh concrete R, the density ρ_C of cement, the density ρ_G of aggregate, the density ρ_F of admixture, and the air amount V_a are measured using the density measuring unit 14 and the air amount measuring unit 15. For example, the density measuring unit 14 measures the densities ρ_W , ρ_C , ρ_G , and ρ_F of the fresh concrete R using Expression (1) described above, and the air amount measuring unit 15 measures the air amount V_a using the Expression (5) described above.

[0060] Further, the air amount measuring unit 15 may measure the air amount V_a of the fresh concrete R by JIS A 1128 (test method based on the pressure of the air amount of fresh concrete) and the like. Then, the density of each component of the fresh concrete R measured by the density measuring unit 14 and the air amount V_a of the fresh concrete R measured by the air amount measuring unit 15 are input to the calculating unit 20 (step of inputting the density and the air amount).

[0061] Note that, instead of the density measurement by the density measuring unit 14, a known density such as a value indicated by a manufacturer may be input to the calculating unit 20. Further, if it is known in advance that the fresh concrete R does not contain the admixture, the measurement of the density by the density measuring unit 14 and the measurement of the air amount by the air amount

measuring unit 15 may be omitted, and the terms of the admixture amount F of Expressions (7) to (9) and Expression (10) may be omitted.

[0062] Next, in the calculating unit 20, the water amount calculating unit 21 calculates the water amount W of the fresh concrete R , the aggregate amount calculating unit 22 calculates the aggregate amount G of the fresh concrete R , the cement amount calculating unit 23 calculates the cement amount C of the fresh concrete R , and the admixture amount calculating unit 24 calculates the admixture amount F of the fresh concrete R (step S3). At this time, the water amount calculating unit 21, the aggregate amount calculating unit 22, the cement amount calculating unit 23, and the admixture amount calculating unit 24 calculate the water amount W , the aggregate amount G , the cement amount C , and the admixture amount F , respectively, using the electric conductivity EC , the temperature T , the unit volume mass UW , the densities ρ_W , ρ_C , ρ_G , and ρ_F , and the air amount V_a which are thus input and Expressions (7) to (10) described above (calculating step).

[0063] After the water amount W , the aggregate amount G , the cement amount C , and the admixture amount F are calculated, the display unit 30 displays the calculated values (step S4). For example, the display unit 30 displays, on the text boxes 31a, 31b, 31c, 31d, 31e, 31f, 31g, and 31h of the display 31, the temperature T , the water amount W , the electric conductivity EC , the unit volume mass UW , the cement amount C , the aggregate amount G , the admixture amount F , and pass/fail of the fresh concrete R , respectively.

[0064] The result of the quality inspection of the fresh concrete R

carried into the construction site is displayed on the text box 31h. Specifically, “pass” is displayed on the text box 31h when the preparation of the fresh concrete R is in a desired state, and “fail” is displayed when the preparation is not in the desired state. After the amount of each component and the pass/fail of the fresh concrete R are displayed, a series of steps is completed.

[0065] As described above, the fresh concrete R is composed of water, cement, aggregate, and admixture. As the fresh concrete R, an erroneous one containing powder different from the cement by reducing the amount of cement may be mixed. When such an erroneous fresh concrete R is carried into the site, the water-cement ratio (ratio of water to cement (W/C)) becomes large in the preparation estimating device 1. Therefore, the preparation estimating device 1 can quickly detect the erroneous fresh concrete R, and can quickly estimate the quality of the fresh concrete R.

[0066] Next, the actions and effects obtained from the preparation estimating method and the preparation estimating device 1 for the fresh concrete R according to the present embodiment will be described. In the preparation estimating method and the preparation estimating device 1 according to the present embodiment, the electric conductivity EC, the temperature T, and the unit volume mass UW of the fresh concrete R are measured, and the water amount W of water, the cement amount C, and the aggregate amount G contained in the fresh concrete R are calculated from the electric conductivity EC, the temperature T, and the unit volume mass UW which are thus measured. As described above, since the water amount W, the cement amount C, and the aggregate amount G

are calculated from the electric conductivity EC, the temperature T, and the unit volume mass UW, the amounts of water and cement, and the aggregate amount contained in the fresh concrete R can be quickly and easily derived.

5 [0067] If the water amount W and the cement amount C are known, the water-cement ratio can be grasped, and the strength of the fresh concrete R can be easily estimated from the water-cement ratio. Specifically, when the ratio of water to cement is high, it can be estimated that the strength of the fresh concrete R is low. As described above, the
10 preparation and strength of the fresh concrete R can be quickly estimated, so that the quality of the fresh concrete R can be efficiently evaluated.

[0068] The fresh concrete R contains admixture. The preparation
15 estimating method according to the present embodiment includes a step of measuring the density of each of water, cement, aggregate, and admixture contained in the fresh concrete R, and a step of measuring the air amount contained in the fresh concrete R. In the calculating step, the water amount W, the cement amount C, the aggregate amount G, and the admixture amount F contained in the fresh concrete R are
20 calculated from the electric conductivity EC, the temperature T, the unit volume mass UW, the densities ρ_W , ρ_C , ρ_G , and ρ_F and the air amount V_a . Therefore, the amount of the admixture can be quickly and easily derived. Further, the strength of the fresh concrete R can be estimated from the admixture amount F, the water amount W, and the cement
25 amount C.

[0069] In the step of measuring the density, the densities ρ_W , ρ_C , ρ_G , and

ρ_F may be calculated in advance before the calculating step is performed. In this case, even when the densities ρ_W , ρ_C , ρ_G , and ρ_F of water, cement, aggregate, and admixture are unknown, by calculating the respective densities ρ_W , ρ_C , ρ_G , and ρ_F in advance, the amounts of water, cement, aggregate, and admixture contained in the fresh concrete R can be calculated quickly. Therefore, the preparation of the fresh concrete R can be estimated more quickly.

[0070] In the step of measuring the air amount, the air amount V_a may be calculated in advance before the calculating step is performed. In this case, even when there is no measuring device configured to measure the air amount V_a at the site, the preparation of the fresh concrete R can be quickly estimated by calculating the air amount V_a in advance. Further, by calculating the air amount V_a in advance, it is not necessary to measure the air amount at the site, so that the preparation of the fresh concrete R can be estimated more quickly.

[0071] In particular, in the present embodiment, the water amount W, the cement amount C, the aggregate amount G, and the admixture amount F are calculated using Expressions (7) to (10) described above, so that the water amount W, the cement amount C, the aggregate amount G, and the admixture amount F can be calculated quickly and accurately. Therefore, in the present embodiment, the preparation of water, cement, aggregate, and admixture in the fresh concrete R can be evaluated highly accurately and quickly.

[0072] The preparation estimating method and the preparation estimating device according to the embodiment of the present invention have been described above. However, the present invention is not

limited to the embodiment described above, and may be modified or applied to other objects without changing the gist described in each claim. That is, the present invention can be variously modified without changing the gist described in each claim.

5 [0073] For example, in the embodiment described above, each of the densities ρ_W , ρ_C , ρ_G , and ρ_F of each component of the fresh concrete R is calculated using Expression (1), and the air amount V_a of the fresh concrete R is calculated using Expression (5). However, each of the densities ρ_W , ρ_C , ρ_G , and ρ_F , of each component and the air amount V_a may be calculated using an expression different from Expression (1) or
10 Expression (5). Further, the water amount W, the cement amount C, the aggregate amount G, and the admixture amount F may be calculated using expressions different from Expressions (7) to (10). As described above, even when the expression different from the expression of the embodiment described above is used, the same effects as those
15 described above can be obtained.

[0074] Further, in the embodiment described above, the preparation estimating device 1 including the electric conductivity measuring unit 11, the temperature measuring unit 12, the unit volume mass measuring unit 13, the density measuring unit 14, the air amount measuring unit 15, the calculating unit 20, and the display unit 30 has been described.
20 However, each configuration of the preparation estimating device 1 may be changed as appropriate. The means for measuring the electric conductivity EC, the means for measuring the temperature T, the means for measuring the unit volume mass UW, the means for measuring the densities ρ_W , ρ_C , ρ_G , and ρ_F , and the means for measuring the air amount
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V_a may be changed as appropriate. Furthermore, the mode of data input to the calculating unit 20, and the display content and display mode of the display 31 of the display unit 30 may be changed as appropriate.

[0075] Further, as described above, known values may be input to the calculating unit 20 as the densities ρ_w , ρ_c , ρ_g , and ρ_f , or the calculation of the admixture amount F may be omitted. In this case, the density measuring unit 14 and the air amount measuring unit 15 may be unnecessary.

[0076] Further, in the embodiment described above, description is made of the example in which the display unit 30 displays the temperature T , the water amount W , the electric conductivity EC , the unit volume mass UW , the cement amount C , the aggregate amount G , the admixture amount F , and pass/fail through the steps of the flowchart shown in FIG.

11. However, in the preparation estimating method according to the present invention, the order and contents of the steps may be changed as appropriate. In particular, the measurement order of the electric conductivity EC , the temperature T , the unit volume mass UW , the densities ρ_w , ρ_c , ρ_g , and ρ_f , and the air amount V_a may be changed as appropriate without being limited to the embodiment described above.

Reference Signs List

[0077] 1 preparation estimating device

11 electric conductivity measuring unit

11a electric conductivity cell

12 temperature measuring unit

13 unit volume mass measuring unit

	14	density measuring unit	
	15	air amount measuring unit	
	20	calculating unit	
	21	water amount calculating unit	
5	22	aggregate amount calculating unit	
	23	cement amount calculating unit	
	24	admixture amount calculating unit	
	30	display unit	
	31	display	
10	31a, 31b, 31c, 31d, 31e, 31f	text box	
	R	fresh concrete	

CLAIMS

1. A preparation estimating method for estimating preparation of fresh concrete containing water, cement, and aggregate, the method comprising:

- a step of measuring electric conductivity of the fresh concrete;
- a step of measuring temperature of the fresh concrete;
- a step of measuring mass per unit volume of the fresh concrete;

and

a step of calculating a water amount of water contained in the fresh concrete, a cement amount of cement contained in the fresh concrete, and an aggregate amount of aggregate contained in the fresh concrete from the electric conductivity, the temperature, and the mass per unit volume.

2. The preparation estimating method according to claim 1, wherein the fresh concrete contains admixture, wherein the preparation estimating method comprises:

a step of measuring density of each of the water, the cement, the aggregate, and the admixture contained in the fresh concrete; and

a step of measuring an air amount contained in the fresh concrete, and

wherein, in the calculating step, the water amount, the cement amount, the aggregate amount, and an admixture amount of the admixture contained in the fresh concrete are calculated from the electric conductivity, the temperature, the mass per unit volume, the

density, and the air amount.

3. The preparation estimating method according to claim 2,
wherein, in the step of measuring the density, the density is
5 calculated in advance before the calculating step is performed.

4. The preparation estimating method according to claim 2 or 3,
wherein, in the step of measuring the air amount, the air amount
is calculated in advance before the calculating step is performed.

10 5. A preparation estimating device configured to estimate
preparation of fresh concrete containing water, cement, and aggregate,
the device comprising:

an electric conductivity measuring unit configured to measure
15 electric conductivity of the fresh concrete;

a temperature measuring unit configured to measure temperature
of the fresh concrete;

a unit volume mass measuring unit configured to measure mass
per unit volume of the fresh concrete; and

20 a calculating unit configured to calculate a water amount of
water contained in the fresh concrete, a cement amount of cement
contained in the fresh concrete, and an aggregate amount of aggregate
contained in the fresh concrete from the electric conductivity, the
temperature, and the mass per unit volume.

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