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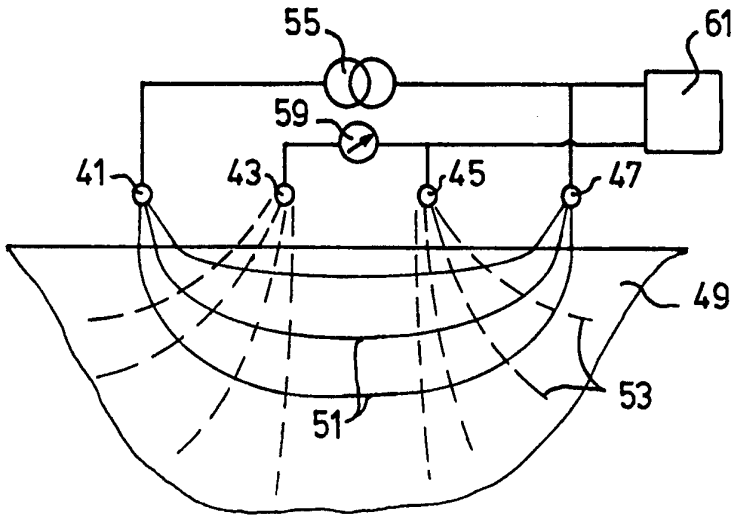

(57) Abstract

The invention relates to a method for determining the degree of hardening of a hardenable material. For this purpose, the complex electrical permittivity is determined. The $\epsilon''(t=0)/\epsilon''(t)$ ratio, where $\epsilon''(t)$ is the imaginary part of the complex electrical permittivity $\epsilon'(t) - j\,\epsilon''(t)$, is determined as a measure of the strength of the material at an instant in time t. The $\epsilon'max/\epsilon'(t)$ ratio of the real part of the complex permittivity can also be determined as a mesure of the strength. Surprisingly, it has been found that these ratios are similar in shape to the curve of the strengths of the hardenable material with time.

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Method for determining the degree of hardening of a material

The invention relates to a method for determining the degree of hardening of hardenable materials, in particular materials which harden as a result of water binding, such as concrete, plaster or cement, in which method the electrical permittivity of said material is determined at various instants in time.

Various methods have been proposed for determining the degree of hardening. The development of the compressive strength, the ageing or the degree of hydration of hardening, setting or curing materials, in particular materials which become hard as a result of water binding, such as hardening stone-like materials such as concrete, cement and plaster. The development of compressive strength, the ageing or the degree of hydration is a measure of the hardening. The most widely known method is to monitor the development of heat during hardening. The development of heat appears to be linked to the extent of water binding, or hydration. However, said method suffers from some disadvantages. One of the most important disadvantages is that the development of heat has to be followed in a conditioned space so that the necessary measurements have to be carried out on one or more test samples in order to predict the degree of hardening of the actual structure on the basis of said measurements. The temperature of the actual structure may, however, differ appreciably from that in the laboratory. In addition, the measurement of the development of heat is inaccurate and susceptible to errors because of the dependence on various parameters.

IEEE PROCEEDINGS - A PHYSICAL SCIENCE, MEASUREMENT & INSTRUMENTATION, MANAGEMENT & EDUCATION, part 137, No. 5, September 1990, STEVENAGE GB, pages 246-254, XP000150889, J.G. WILSON ET AL.: "VARIATIONS IN THE ELECTRICAL PROPERTIES OF CONCRETE WITH CHANGE IN FREQUENCY" describes how the dielectric constant (or the electrical permittivity) and the conductivity alters for concrete during hardening over a period of not more than 1 day. No indication is given of how the degree of hardening of the concrete can be determined reliably and accurately from the observed change in said parameters.

The object of the present invention is to provide a more accurate method for determining the degree of hardening of a material. Moreover, the subject of the invention is a more reliable method of this type. The object of the invention is also to provide a method with which the degree of hardening of the material can be measured accurately and

reliably, without the need for separate test samples, directly on the structure itself, preferably in a particularly simple and not very time-consuming manner.

For this purpose, the method according to the present invention is characterised in that the ratio $\varepsilon''(t=0)/\varepsilon''(t)$ of the imaginary part, $\varepsilon''(t)$, of the complex electrical permittivity, $\varepsilon'(t)-j\varepsilon''(t)$, at a reference instant in time t=0 and at an instant in time t and/or the ratio $\varepsilon'max/\varepsilon'(t)$ of the maximum value of the real part of the complex electrical permittivity, $\varepsilon'max$, over the time interval t=0 to t and the real part of the complex electrical permittivity, $\varepsilon'(t)$, at the instant in time t are/is determined as a measure of the strength of the material at an instant in time t.

The dielectric behaviour of a material such as concrete can be described by the complex dielectric constant, also referred to as the complex electrical permittivity. The complex permittivity ε can be expressed as:

$$\varepsilon = \varepsilon' - j\,\varepsilon''.$$

In this equation, the real part of the permittivity, ε', is a measure of the polarizability of various material constituents, including the water, which is in some cases bound. The imaginary part of the permittivity, ε'', is a measure of the absorption of energy. The ionic conductivity contributes to ε''. The two components ε' and ε'' of the permittivity are measurable, respectively, as the capacitance C (in farads) and the conductivity G (in Sm^{-1}) of a capacitor having the hardenable material as dielectric between the electrodes.

The reorientation of a polarizable particle such as water in an alternating electric field requires some time. For increasing frequency, the particles or molecules are too slow to be able to follow the rapidly alternating field. This slowness is influenced, inter alia, by the degree to which the particle or the molecule is bound to its environment. For higher frequencies, ε' then decreases. At higher frequencies, the energy supplied is absorbed, as a result of which the dielectric losses, of which ε'' is a measure, increase. For frequencies lower than those at which the most important absorptions take place, ε'' is dominated by the ionic conductivity.

As the forces which bind the water molecule to its environment in the hardenable material increase during its ageing, the strength of the material in newtons per m^2 can be determined from the real part ε' of the complex electrical permittivity or from the imaginary part ε''.

Surprisingly, it has been found that, apart from a scaling factor, the curve of $\varepsilon''(t=0)/\varepsilon''(t)$ against time is to a high degree similar in shape to the curve of the compressive strength of the hardenable material in newtons per m^2. The hardening process of the hardenable material can be followed reliably by determining $\varepsilon''(t=0)/\varepsilon''(t)$ at regular intervals, for example over a period of, for example, a few days to a few weeks. The ratio is insensitive to disturbances in the electrode/dielectric configuration during the measurement.

It has also been found, surprisingly, that the ratio $\varepsilon'max/\varepsilon'(t)$ correlates very well with the strength of the hardenable material after a hardening period of approximately one day.

Advantageously, the imaginary part, $\varepsilon''(t)$, of the complex electrical permittivity can be determined by placing at least two electrodes in or near the hardenable material, applying an alternating current across the electrodes, measuring the alternating voltage across the electrodes, determining the complex impedance Z^*, where $Z^* = \frac{1}{G+j\omega C}$, where G is the conductivity of the hardenable material in S/m and C is the capacitance in F, and determining $\varepsilon''(t)$ via the relationship: $G(t)=k\ \varepsilon''(t)\ \varepsilon_0.\omega$ and/or determining $\varepsilon'(t)$ via the relationship: $C(t) = k\ \varepsilon'(t)\ \varepsilon_0$, where k is a constant.

By placing two electrodes in the hardenable material, in which arrangement the electrodes may, for example, be cylindrical with a length of, for example, 3 cm and a diameter of 1 cm and placed at a mutual spacing of 2 cm, a capacitor is formed with the electrodes as capacitor plates and the hardenable material in between as dielectric. The complex impedance can be determined by measuring the alternating voltage. Said complex impedance is formed by the conductivity G (in Sm^{-1}, where $S=\Omega^{-1}$), from which the imaginary part $\varepsilon''(t)$ of the complex electrical permittivity can be determined, and the capacitance C from which the real part $\varepsilon'(t)$ of the complex electrical permittivity can be determined. In this connection, the constant k is a geometry factor which depends on the shape and mutual positioning of the electrodes. As a result of setting up the electrodes and measuring the complex impedance with them, the strength of the hardenable material can be determined very simply and reliably in situ without complex equipment being necessary.

Preferably, the strength of the material is determined over a time of between 1 day and 100 days, preferably of between 1 day and 30 days. The frequency used can be between 0 and 17 GHz and is preferably

between 15 and 50 MHz. It has been found that, at frequencies below 20 MHz, interfering effects may occur, for example, as a consequence of electrode polarization. Although a relationship between the complex permittivity and the compressive strength is found at higher frequencies, for example above 100 MHz, it is less sensitive and less easy to measure.

As a measure of the strength of the hardenable material, $r.\varepsilon''(t=0)/\varepsilon''(t)$ preferably is determined, where r is a scaling factor which depends on the composition of the hardenable material. To determine r, a calibration measurement is made prior to the measurement. It is also possible to determine r by determining the maximum value of the real part of the complex electrical permittivity, $\varepsilon'max$, which will occur within approximately 1 day after the start of hardening of the hardenable material. The strength can then be calculated from the ratio of $\varepsilon'max$ and $\varepsilon'(t)$. The scaling factor r can be calculated with this calculated strength. The strength curve can then furthermore be determined using the relationship $r.\varepsilon''(t=0)/\varepsilon''(t)$. The scaling factor r can furthermore be determined from the fact that, for $\varepsilon'max(t)$, the compressive strength appears to be 10.5 N/mm^2.

A device for carrying out the method according to the invention comprises an alternating-current source for supplying an alternating current via a supply lead to a supply terminal of the electrodes. Via a branching lead, the alternating current of the current source is also supplied via a switch to a phase-rotating component, such as, for example, a capacitor, or to a non-phase-rotating component, such as a resistor. The voltage which is generated across the electrodes of the measuring arrangement with the hardenable material in between as dielectric and the voltage which is generated across the phase-rotating component or the non-phase-rotating component on the branching lead are multiplied by one another in a multiplier. The output voltage of the multiplier comprises an alternating-voltage component and a direct-voltage component. The alternating voltage is removed by a low-pass filter. If the current in the branching lead is fed via the non-phase-rotating component to the multiplier, the direct current is a measure of the capacitance, C, and if a phase rotation has taken place, the direct current is a measure of the conductivity, G. These values are fed via an analogue/digital converter to a computer in which the real part and/or the complex part of the complex electrical permittivity are determined from the conductivity and the capacitance and a measure of the strength is calculated. With the aid of a time control unit, a number of

measurements are made, for example every hour for a number of days, for example seven days.

The method for determining the strength of hardenable material according to the invention can advantageously be used in fabricating a structure from a hardenable material, such as, for example, concrete. In this case, the material is placed in a soft state in a casing, such as, for example, a form. The instant at which the casing can be removed on reaching a predetermined strength can be determined by installing the electrodes in the curing material and determining the strength according to the method according to the invention.

More detailed information on the measurement of dielectric properties is to be found in Hasted, J.B., "Aqueous dielectrics", Chapman and Hall, London, 1973.

It has been found, that in the case of materials which harden as a result of water binding, such as plaster, cement or concrete, the progress of the hardening, or the hydration process, can be satisfactorily reproduced in the change in the dielectric properties described above as a function of time. The change in the dielectric properties as a function of time can be measured as a measure of the degree of hardening at various frequencies of the electric field. In the experiments, good results have been obtained, for example, at frequencies between 10 and 50 MHz. The most reliable are the relative changes with respect to an earlier situation, that is to say each subsequent measurement in time is compared in each case with the measurement during, for example, the initial situation. As a result of measuring the dielectric properties of the hardening material at various instants in time and comparing these measurement results with one another, the method according to the present invention is essentially insensitive to variations in the composition of the hardening material. If the probes with which the measurement of the dielectric properties is carried out remain essentially unchanged in position for the measurements at different instants in time, the measurement is, moreover, essentially insensitive to local differences in composition of the material (consider, for example, gravel in concrete which has not been completely homogeneously mixed). It has, moreover, been found that by measuring the dielectric properties of the hardening material at various instants in time and comparing the measurement results with one another, there is essentially no sensitivity to scale and calibration errors. It has been found that the ratio of the dielectric losses at the instant when the

hardenable material is prepared and at a later instant in time correlates well with the degree of hardening of said material. If said material is, for example, concrete, said ratio is a direct indication of the compressive strengths reached by said concrete.

In addition to determining a relative indication of the degree of hardening, the method according to the present invention can also be used to indicate the degree of hardening in an absolute sense. For this purpose, the measured dielectric properties can be compared with dielectric properties determined on test samples having the same or similar composition, or by means of conversion on the basis of, for example, an empirically determined formula or a conversion table.

An embodiment of the method and a device according to the present invention will be explained in greater detail by reference to the accompanying drawing. In the drawing:

Figure 1 shows the curve of the strength in N/mm^2 of curing Portland A concrete and the ratio $\varepsilon'(t=0)/\varepsilon''(t)$ for a time span of 160 hours,

Figure 2 shows the curve of the calculated compressive strength $S1=53(\varepsilon'max/\varepsilon'(t)-0.78)$ and $S2=r\varepsilon''(t=0)/\varepsilon''(t)$ and the measured strength of the curing concrete,

Figure 3 diagrammatically shows the circuit for carrying out the dielectric measurements according to the invention,

Figure 4 shows an arrangement in which the electrodes are situated in the hardenable material, and

Figure 5 shows an arrangement in which four electrodes are situated at a distance from the hardenable material.

To measure the strength of concrete as reproduced graphically in Figure 1, a test was carried out to determine the complex electrical permittivity of curing Portland A cement having a water/cement ratio of 0.53. The cement was poured into a cube made of expanded polystyrene measuring 15.5 cm x 15.5 cm x 15.5 cm. The cubes were then covered with a plastic sheet and sealed with an expanded polystyrene lid. The compressive strength in N/mm^2 of the cubes was followed as a function of time. During this procedure the cubes were pressure-loaded until a critical pressure was reached at which the cubes fell apart. Further details of a strength measurement of this type are described in Hasted, J.B. "Aqueous Dielectrics".

Two cylindrical electrodes having a length of 3 cm and a diameter of 1 cm were also placed at a mutual spacing of 2 cm in the

curing concrete. The complex electrical permittivity was measured at frequencies of 10 MHz, 20 MHz and 30 MHz over a time of 28 days. It was found that the relationship r $\varepsilon''(t=0)/\varepsilon''(t)$, where r is a scaling factor which depends on the composition of the concrete, very closely follows the strength curve, as measured for the concrete cubes by means of the pressure tests, with the passage of time, as is evident from Figure 1.

Since the electrical conductivity $G=k\ \varepsilon''\varepsilon_0\omega$, the ratio $G\ (t=0)/G(t)$ will also provide a good measure of the strength of the hardenable material.

In a further test, a concrete sample was taken from a commercial concrete mixing factory which had a water/cement ratio of between 0.45 and 0.55 and for cement types CEM III/B42.5LH HS, CEM I 32.5R, CEM I 42.5R. The concrete was again poured into a cubic form in the same way as described above in connection with Figure 1. A similar electrode pair was used to measure the electrical permittivity at 20 MHz. The strength of the test cubes was also measured by uniformly pressure-loading them, the pressure at which the cubes collapsed being taken as the strength values.

The measured values for the imaginary part ε'' of the complex permittivity were corrected for temperature defects (2%/°C). A first strength S1 was calculated according to the empirical formula: $S1=53(\varepsilon'max/\varepsilon'(t)-0.78)$.

A second strength S2 was calculated according to the formula: $S2=r\ \varepsilon''(t=0)/\varepsilon''(t)$.

Here $\varepsilon'max$ is the maximum value of the real part of permittivity which is found as a function of the time elapsed t. The value r is a scaling factor which depends on the composition of the concrete. As is evident from Figure 2, the force per unit area S1 alone is a good reflection of the strength after $\varepsilon'max$ has occurred, while the force value per unit area S2 is valid from instant in time t=0.

As is evident from Figure 2, there is a good fit between the calculated forces per unit area S1 and S2 and the measured strength of the concrete samples. The calculated forces S1 and S2 are relatively insensitive to temperature and composition and factors such as the electrode dimensions and any stones between the electrodes. The calculated value S1 was universally applicable, while a scaling factor r had to be determined for S2 to obtain a better fit with the measured force S. The maximum difference between the measured force S and S1 was approximately 6 N mm^2, which is close to the accuracy of standard methods

of determining the strength.

The scaling factor r can advantageously be determined by measuring the force S1 at $\varepsilon'max$, which is approximately 10.5 newtons/ mm^2 in Figure 2. By then postulating that $10.5 = r\ \varepsilon''(t=0)/\varepsilon''(t)$, the factor r can be determined.

Figure 3 diagrammatically shows the measurement arrangement for determining the real part $\varepsilon'(t)$ and the imaginary part $\varepsilon''(t)$ of the complex permittivity. The electrode configuration with the hardenable material in between as dielectric is represented as a complex impedance Z^*. Via a supply line 1, an alternating current is supplied via a switch 3 to a supply terminal 5 of the impedance Z^*, which is formed by two or more electrodes with hardening material in between as dielectric. The alternating current source 7 is formed by a crystal oscillator which generates a sinusoidal current having an adjustable oscillator frequency of between 1 MHz and 100 MHz. The output signal of the oscillator 7 is supplied to a switch 11 via a branching line 9. The switch 11 can be selectively connected to a phase-rotating component such as a capacitor 13 or a non-phase-rotating component such as a resistor 15. The supply terminal 5 of the electrode configuration and the supply terminal of the capacitor 13 or the resistor 15 are connected to a multiplier 17, the voltages formed across the electrode configuration Z^* and the component 13 or 15, U_z and U_{shift} respectively, being multiplied by one another. The product $U_z \cdot U_{shift}$ is supplied to a low-pass filter 19. The signal at the output of the low-pass filter 19 is converted in an analogue/digital converter 21, whose output is connected to the input of an arithmetic unit 23. In the arithmetic unit 23, the real part $\varepsilon'(t)$ and the imaginary part $\varepsilon''(t)$ of the complex permittivity are determined. The relationships $53.(\varepsilon'max/\varepsilon'(t)-0.78)$ and/or $\varepsilon''(t=o)/\varepsilon''(t)$ are then calculated in the arithmetic unit 23. By means of a time control unit 25, the switches 3, 11, the analogue/digital converter 21 and the arithmetic unit 23 are triggered to make a measurement at predetermined time intervals, for example every hour over a period of, for example, 30 days.

The measurement of the impedance Z^* of the electrode configuration is based on synchronous detection. The sinusoidal voltage having a frequency ω which is chosen between 1 MHz and 100 MHz is fed to the multiplier 17. The phase of the current which is fed via the branching line 9 to the multiplier 17 can be rotated through 0° or 90° in phase by positioning the switch 11. The voltage U_z which is developed on the supply terminal of the phase-rotating component 13 or the non-phase-

rotating component 15 is fed to the other supply terminal of the multiplier 17. The output voltage $U=U_z U_{shift}$ of the multipliers has a frequency component having a frequency 2 ω and a direct-voltage component. The low-pass filter 19 removes the alternating-voltage component having a frequency 2 ω. If the switch 11 is connected to the resistor 9, no phase rotation takes place and the direct voltage is a measure of the capacitance of the impedance Z^*. If the switch 11 is connected to the capacitor 13, the voltage on the output terminal thereof is rotated through 90°. This voltage is a measure of the conductivity G of the impedance Z^*. Since

$Z^*=1(G+j\ \omega\ C) = 1/j\ \omega\ (\varepsilon' + j\ \varepsilon'')\ \varepsilon_0 k)$, ε' and ε'' can be calculated here in the arithmetic unit 23.

The measurements are repeated for a reference impedance Z_{ref} to calibrate the sensor automatically. Preferably, the circuit in Figure 3 is embodied as an integrated circuit in the form of an ASIC.

Figure 4 diagrammatically shows an electrode configuration, in which two electrodes 30, 31 are installed in a layer of hardenable material 33. The electrodes are connected to an alternating-current source 35. The current tracks between the electrodes 30, 31 are indicated diagrammatically by 37. The voltage generated by the current flowing between the electrodes 30, 31 is measured across the supply terminals of said electrodes with the aid of a voltmeter 39. The output signal of the voltmeter 39 is fed to a signal processing unit 40, which comprises, for example, a multiplier 17, a low-pass filter 19, an analogue/digital converter 21, an arithmetic unit 23 and a time control unit 25, as shown in Figure 3.

Figure 5 shows an alternative arrangement, in which four electrodes 41, 43, 45 and 47 are situated above a base 49. The current paths are indicated by 51 and the equipotential lines by 53. With the aid of a current source 55, a current is fed along current paths 51 through the material 49 from an electrode 41 to an electrode 47. The potential formed in the material 49 is measured with the aid of the electrodes 43, 45. The output of the voltmeter 59 is connected to a signal processing unit 61, which may comprise the same components as the signal processing unit 40 of Figure 4. The advantage of the arrangement according to Figure 5 is that no electrodes have to be installed in the material 49 and that the hardening process of the latter can be observed at a distance without damaging the material.

CLAIMS

1. Method for determining the degree of hardening of hardenable materials, in particular materials which harden as a result of water binding, such as concrete, plaster or cement, in which method the electrical permittivity of the material is determined at various instants in time, characterized in that the ratio $\varepsilon''(t=0)/\varepsilon''(t)$ of the imaginary part, $\varepsilon''(t)$, of the complex electrical permittivity $\varepsilon'(t) - j\varepsilon''(t)$ at a reference instant in time t=0 and at an instant in time t and/or the ratio $\varepsilon'max/\varepsilon'(t)$ of the maximum value of the real part of the complex electrical permittivity $\varepsilon'max$ over the time interval t=0 to t and the real part of the complex electrical permittivity $\varepsilon'(t)$ at the instant in time t are determined as a measure of the strength of the material at an instant in time t.

2. Method according to Claim 1, wherein the imaginary part of the electrical permittivity $\varepsilon''(t)$ is determined by placing at least two electrodes in or near the hardenable material, applying an alternating current across the electrodes, measuring the alternating voltage across the electrodes, determining the complex impedance $Z^*=\frac{1}{G+j\omega C}$, where G is the conductivity of the hardenable material in S/m and C is the capacitance in F, and determining $\varepsilon''(t)$ via the relationship: $G(t) = k\ \varepsilon''(t)\varepsilon_0.\omega$ and/or determining $\varepsilon'(t)$ via the relationship: $C(t) = k\ \varepsilon'(t)\ \varepsilon_0$, where k is a constant.

3. Method according to Claim 1 or 2, characaterized in that the time during which the hardness is determined is between 1 day and 100 days, preferably between 1 day and 30 days.

4. Method according to one of the preceding claims, characterized in that the imaginary part, $\varepsilon''(t)$, of the complex electrical permittivity $\varepsilon'(t) - j\varepsilon''(t)$ is determined at a frequency between 0 and 17 GHz, preferably between 15 and 50 MHz.

5. Method according to one of the preceding claims, characterized in that, prior to the measurement of $\varepsilon''t)$, a calibration is carried out to determine the scaling factor, r, which depends on the composition of the hardenable material and in that the ratio $r.\varepsilon''(t=0)/\varepsilon''(t)$ is then determined as a measure of the strength of the material.

6. Method according to Claim 5, characterized in that, as calibration, the strength is determined at the maximum value of the real part of the permittivity, $\varepsilon'max$, the ratio $\varepsilon''(t=0)/\varepsilon''(t)$ is determined for the instant in time at which $\varepsilon'max$ is found, after which the scaling

factor r is determined, the strength being determined for later instants in time by $r.\varepsilon''(t=0)/\varepsilon''(t)$.

7. Device for carrying out the method according to one of Claims 1 to 6 inclusive, characterized in that the device comprises:

- at least two electrodes which can be connected to the hardenable material,
- an alternating-current source for supplying an alternating current to a supply terminal of the electrodes via a supply line,
- a switching device for selective connection of the alternating-current source via a branching line to a supply terminal of a phase-rotating component or a non-phase-rotating component,
- a multiplier whose input is connected to the supply terminal of the electrodes and to the switching device,
- a low-pass filter whose input is connected to the output of the multiplier,
- an arithmetic unit connected to the low-pass filter for determining the conductivity and/or the capacitance according to Claim 2 and for determining $\varepsilon''(t=0)/\varepsilon''(t)$ and/or $\varepsilon'max/\varepsilon(t)$ and
- a time control unit for reading-in signals at the output of the filter at a number of consecutive instants in time.

8. Method for fabricating a structure made of hardenable material, comprising placing the material in a soft state in a casing, determining the strength according to one of Claims 1 to 6 inclusive, and removing the casing when a predetermined strength is reached.

fig-1

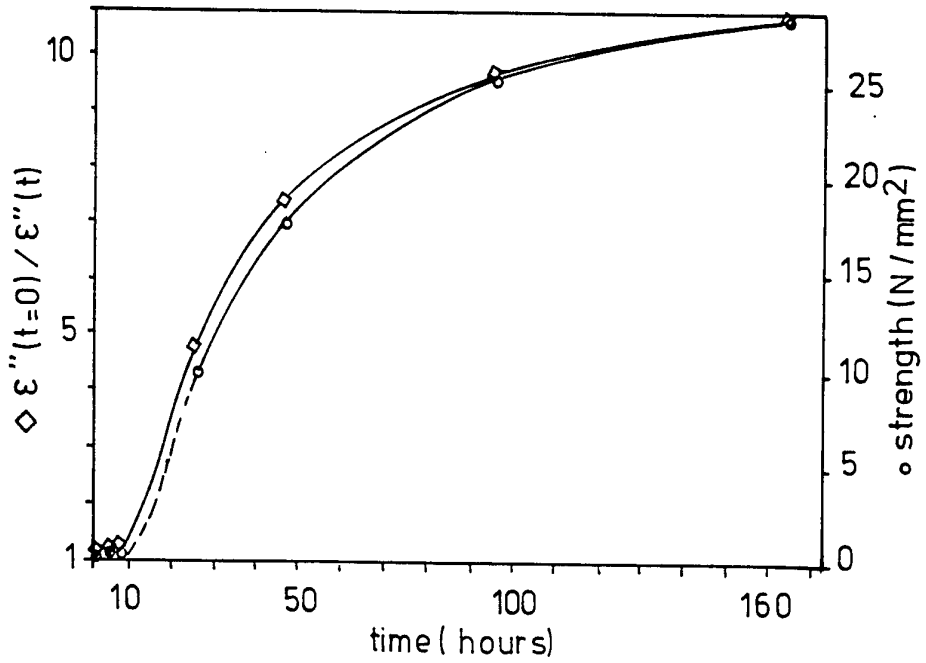

10
5
1
◇ ε''(t=0) / ε''(t)
25
20
15
10
5
0
∘ strength (N / mm2)
10
50
100
160
time (hours)

fig-2

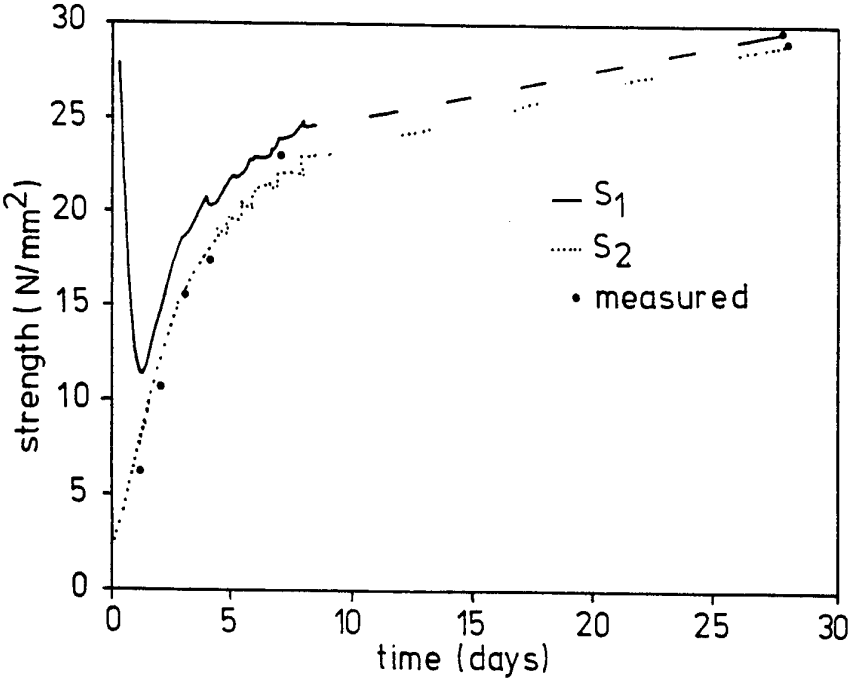

30
25
20
15
10
5
0
strength (N/mm2)
— S1
····· S2
• measured
0
5
10
15
20
25
30
time (days)

Fig-3

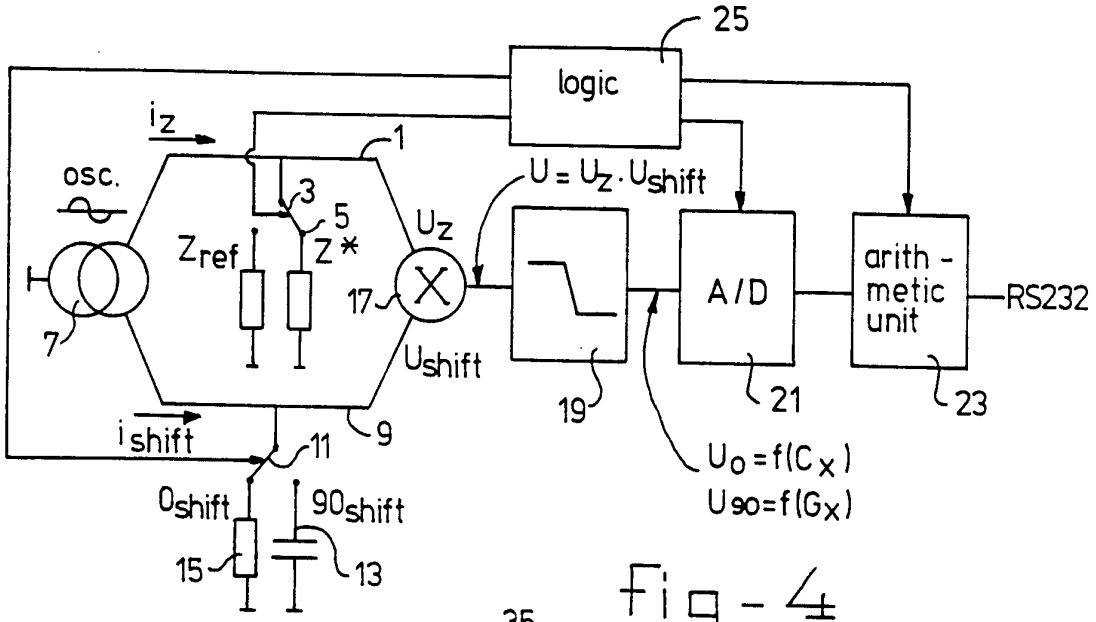


Fig-4

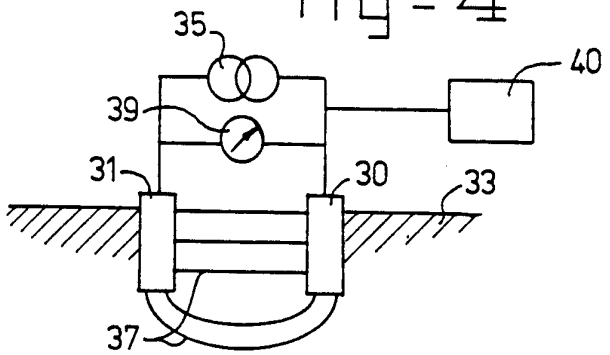
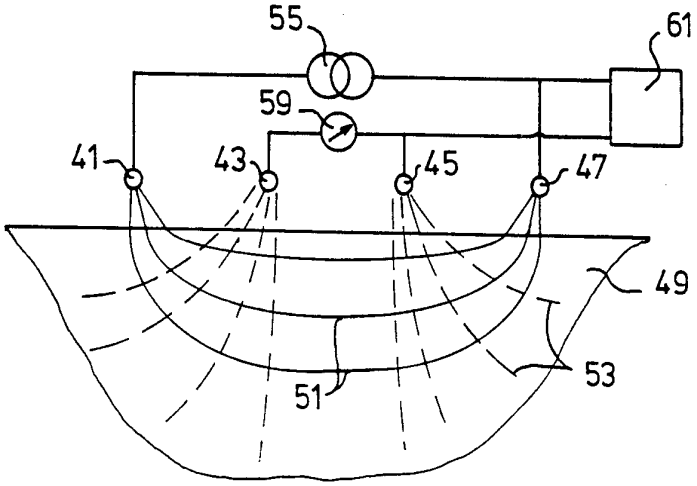


Fig-5



INTERNATIONAL SEARCH REPORT

In ıtional Application No
PCT/NL 96/00228

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01N33/38 G01N27/22 G01N27/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	IEE PROCEEDINGS A PHYSICAL SCIENCE, MEASUREMENT & INSTRUMENTATION, MANAGEMENT & EDUCATION., vol. 137, no. 5, September 1990, STEVENAGE GB, pages 246-254, XP000150889 J.G. WILSON, ET AL.: "VARIATIONS IN THE ELECTRICAL PROPERTIES OF CONCRETE WITH CHANGE IN FREQUENCY" cited in the application see the whole document ---	1-7
A	FR 2 484 092 A (BELORUSSKY POLITEKHNICHESKY INSTITUT) 11 December 1981 see page 6, line 11 - page 14, line 37; figures 1-7 ---	1-7
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 August 1996	29.11.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	BOSMA, R

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INTERNATIONAL SEARCH REPORT

In tional Application No
PCT/NL 96/00228

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JOURNAL OF PHYSICS D APPLIED PHYSICS., vol. 23, no. 2, 14 February 1990, LETCHWORTH GB, pages 234-236, XP000099844 M.A. BARI: "COMMENT ON 'DYNAMIC DIELECTRIC ANALYSIS DURING EARLY-STAGE HYDRATION OF ORDINARY PORTLAND CEMENT'" see the whole document ---	1-7
A	DATABASE WPI Week 8109 8 April 1981 Derwent Publications Ltd., London, GB; AN 81-B8665D [09] XP002000070 & SU 742 784 A (DNEPR UNIV) , 26 June 1980 see abstract ---	1,7
A	US 4 399 100 A (ZSOLNAY ET AL.) 16 August 1983 see column 4, line 23 - column 5, line 61; figures 1-3 ---	1,7
A	FR 2 645 275 A (BARTOLO, RENA) 5 October 1990 see page 5, line 35 - page 12, line 8; figures -----	1,7

1

INTERNATIONAL SEARCH REPORT

ernational application No.
PCT/NL 96/00228

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. claims 1-7: method and device for determining the degree of hardening of e.g. concrete
2. claim 8: method of fabricating a structure made of hardenable material

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searches without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-7

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

In ational Application No
PCT/NL 96/00228

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
FR-A-2484092	11-12-81	SU-A-	1004000	15-03-83
		AU-B-	544145	16-05-85
		DE-C-	3152081	08-09-88
		SE-B-	439739	01-07-85
		SE-A-	8200333	21-01-82
		WO-A-	8103450	10-12-81
US-A-4399100	16-08-83	US-A-	4496697	29-01-85
FR-A-2645275	05-10-90	NONE		