

(21) Application No 0109234.5

(22) Date of Filing 12.04.2001

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(51) INT CL⁷

G01N 15/08

(52) UK CL (Edition T)

G1S SGX

(56) Documents Cited

GB 2280512 A

WO 1996/002627 A1

US 5503001 A

(58) Field of Search

UK CL (Edition S) G1S SGX

INT CL⁷ G01N 15/08

On-line: EPODOC,WPI,JAPIO

(54) Abstract Title

Porosity measuring device for building materials

(57) A simple porosity-measuring device accurately determines porosity of clays, soils and building materials by utilising the electroosmotic flow characteristics of a glass capillary. This apparatus consists of two transparent vertical reservoirs 2, joined by screw threads 5 to a sample holder 4. Two electrode compartments 1 are mounted into each reservoir via screw threads 13. Pressure head differences between two water or other electrically conducting solvent-filled reservoirs are measured with a digital camera. Bubbles associated with the electrolytic dissociation of the solvent are prevented from migration into the porosity determining area 4 by baffle and filter arrangements 3,(15) located in the electrode compartments. Distance measurements are then fitted to a height-time graph and the porosity calculated. Meniscus height changes in the reservoirs are taken with a digital camera (18) and recorded on a pc or data processor (19).

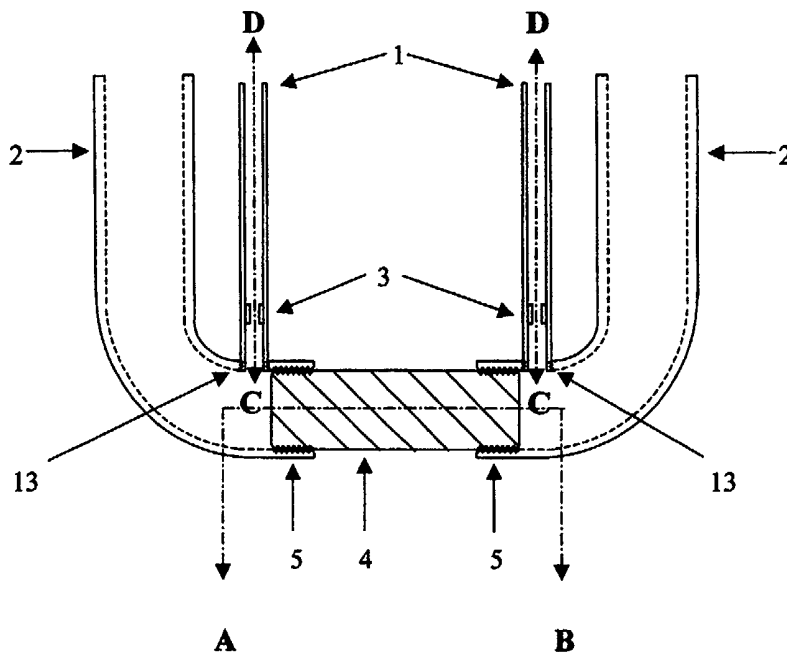


FIG. 1

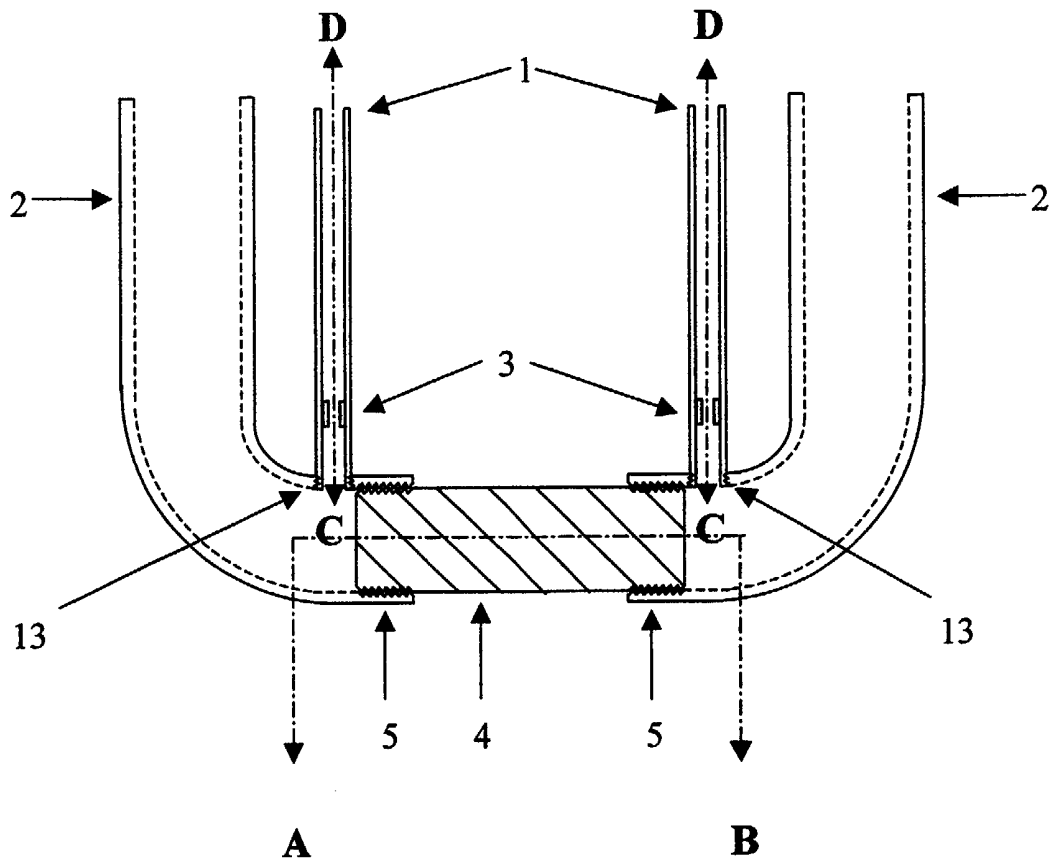


FIG. 1

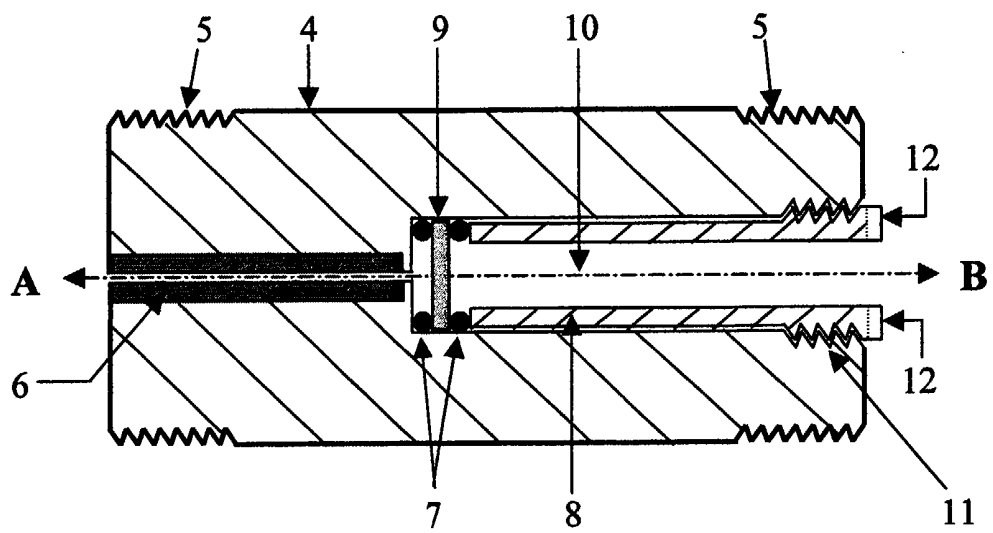


FIG. 2

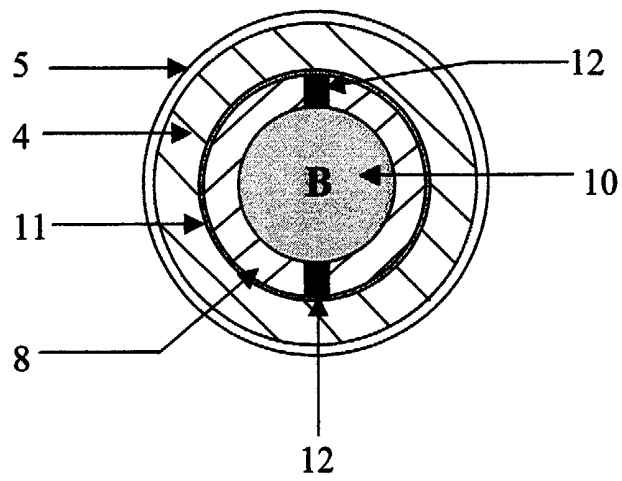


FIG. 3

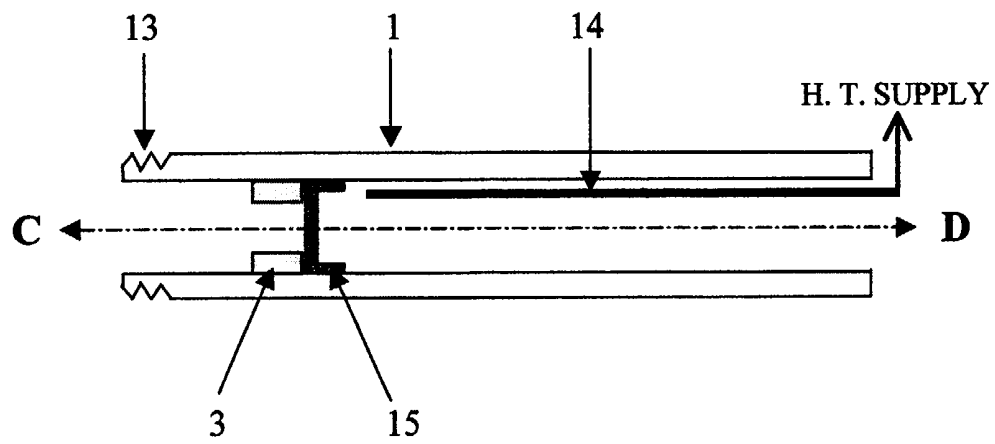


FIG. 4

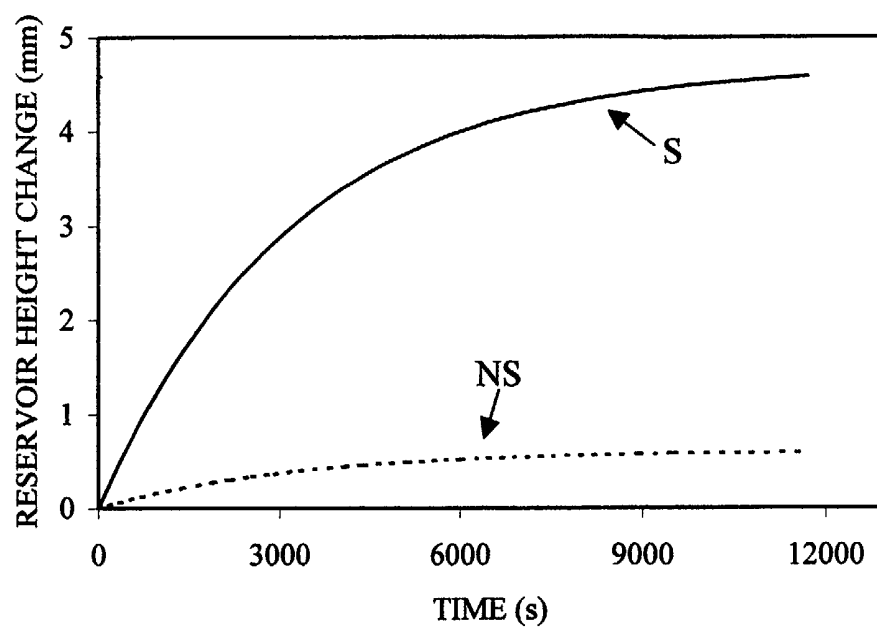


FIG. 5

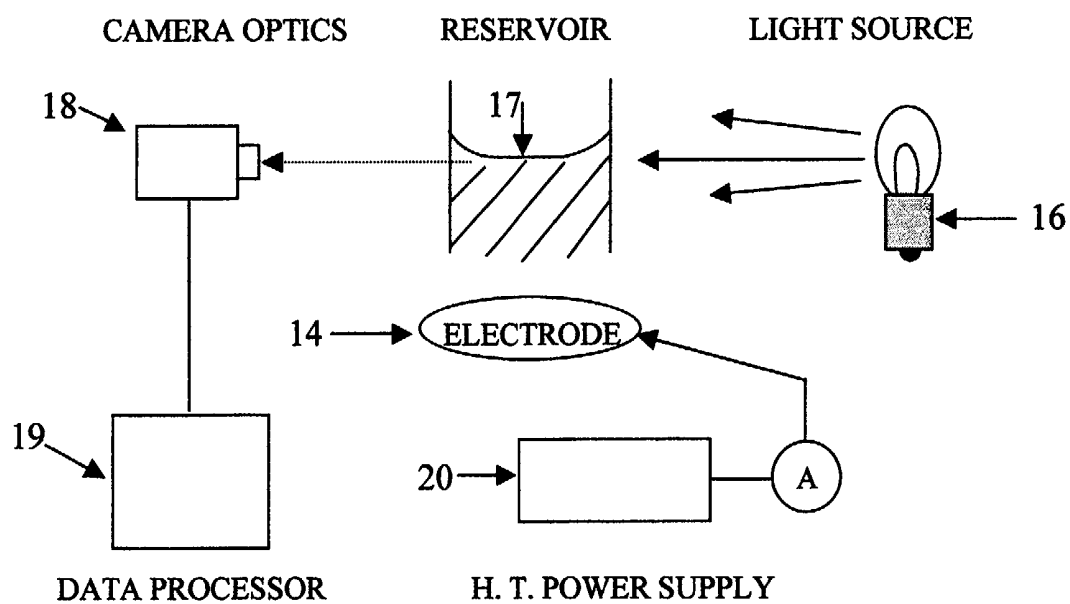


FIG. 6

A Simple Porosity-Measuring Device For Building Materials.

DESCRIPTION.

A. Background of the invention.

Knowledge of the porosity and permeability of a material is almost as important as knowing the strength and durability in the building industry. Without physical testing, designing and creating safe structures would be impossible. Engineers need to understand the process of weathering and be able to estimate the useful working lifetime of a stone.

Porosity is really the only fundamental physical quantity measurable, which can give an insight into the decay process (especially at a microscopic level). For it is the water logged pores in the stone matrix that become fractured and crumble from the repeated freeze-thaw cycles attributed to the changing seasons.

At the other end of the spectrum hydrologists and oil field engineers require a detailed knowledge of the rock strata and its porosity, in order to make extraction cost effective and reservoirs that do not leak.

Conventionally, thin sections are made from rock samples taken from these beds and viewed under a microscope. Prior treatment of the rock with a water based dye helps highlight pore spaces. Another method of measuring pore size is to see what pressure is needed for mercury to permeate through a test sample of known dimensions at room temperature.

Both the porosity techniques mentioned above have several disadvantages. Thin sections are time consuming to prepare because of the precision grinding required and so are not designed for high sample numbers. While they can yield extra information about rock structure, the technique is inadequate and does not provide an absolute measure of porosity. On the other hand, high-pressure mercury provides the best results with high sample throughput and absolute measurement, but suffers the drawback of using mercury.

B. Summary of invention.

The object of the current invention is to provide a device, which is able to give absolute porosity measurements with a high sample throughput and the minimum experimental preparation. The additional bonus is that mercury is dispensed with.

Accordingly, this invention provides a method of absolute measure for porosity by an electroosmotic means. Porosity of soils and building stones are determined by tracking the pressure head of a moving column of water or other polar, electrically conducting solvent under the influence of an applied electric field, by means of a digital camera imaging a transparent reservoir.

Preferably the column of water is tracked in a transparent tube made from Perspex or polycarbonate plastic. The main components of this apparatus are the reservoirs and sample holder, which can alternatively be made from glass or other plastics so long as it is transparent and not too difficult to machine. The electrode compartments with bubble filters form the remaining features. The bubble filters are made either of filter paper or cotton wool.

C. Brief description of the drawings.

A preferable embodiment for this invention will now be described with reference to the accompanying drawings.

FIG. 1 shows a front view of the apparatus with reservoirs, electrodes and sample section fully assembled. Supporting frame is omitted for clarity.

FIG. 2 is a cross section view showing the sample holder along axis AB.

FIG. 3 shows the end profile of the sample holder looking along section AB, as seen from end B.

FIG. 4 is a cross section of one of the electrode compartments along axis CD shown in FIG. 1.

FIG. 5 shows a graph of the height change for a reservoir as a function of time. The graph was obtained by using the present embodiment of this invention.

FIG. 6 is a schematic representation of how height change measurements were made using the digital camera and computer recording system.

The drawings are not to scale.

D. Detailed description of the preferred embodiments.

A porosity-measuring device according to the first embodiment of the present invention is shown in FIGS. 1 to 4. As shown in FIG. 1 the apparatus consists of two identical cylindrical Perspex reservoirs 2 that are joined to a sample holder 4, by screw threads 5 at either end of the sample holder. Mounted along the tops of the reservoirs along axis AB are the electrode compartments 1. These again are secured by screw threads 13.

N.B. All major components are structurally secured by screw threads since they allow ease of cleaning and storage. Joints are made leak tight by using plumbers PTFE tape.

The sample holder can be seen in detail from FIG. 2 to comprise of a solid piece of Perspex rod 4 which has been turned to yield screw threads 5, quartz glass capillary 6 and sample chamber 10. The sample of porous material to be examined 9 is held between two rubber O-rings 7, which gently press it against the end of the sample chamber and the "key" 8. The key forms a close fitting tube, which inserts into

the sample chamber and provides a firm grip on the sample through screw thread 11. The sample mounting pressure is adjusted by turning the key clockwise with a screwdriver in the notches 12 provided.

Looking along the AB axis of the sample holder towards the sample as in FIG. 3, the cylindrical channel can be viewed. This serves as a void for solvent to occupy and hence fluid to flow when the electric field is applied. The potential difference is applied across platinum (Pt) electrodes 14 shown in FIG. 4. The electrode housing 1 is again Perspex tubing. Within the housing, there is a plastic baffle 3 that a piece of filter paper 15 buffs up to. With the electrodes on the opposite side of the filter paper to the main flow region, gas bubbles associated with the dissociation of the solvent cannot migrate into the capillary 6 and stop the experiment. The bubbles are free to migrate upwards unhindered and escape from the system. With this arrangement they do not alter the liquid volume or disturb the meniscus definition as is the case if electrodes are located in the measurement reservoir.

This system works by utilising the dynamic equilibrium of pressures set up when water is forced to flow from an anode to a cathode under the influence of an applied electric field (electroosmosis). As water flows in one direction it starts to fill the reservoir ahead of the flow. After a certain time the filling subsides as the hydrostatic back pressure equals the electroosmotic driving pressure, at which point a state of equilibrium is achieved. Based on this idea equations were derived to model the differences between an open capillary and a soil filled capillary.

The equation derived relates the rate of change of reservoir height δL over time to the porosity Φ and intrinsic permeability K_i :

$$\frac{d\delta L}{dt} = \frac{E\epsilon_0\epsilon_r A_c \Phi \zeta}{\eta A_r} - \frac{K_i \Phi A_c \rho g}{\eta l_c A_r} \delta L \quad (\text{EQN. 1})$$

E is the electric field strength, ϵ_0 permittivity of free space, ϵ_r relative permittivity, η viscosity of polar solvent, ρ density of polar solvent, g the acceleration due to gravity, ζ is the zeta potential of the capillary-solvent interface, A_r the average cross sectional area of the reservoirs, A_c is the cross sectional area of the capillary and l_c is the capillary length plus sample thickness.

Integration of EQN. 1 gives the height change in terms of porosity and time EQN. 2:

$$\delta L = \frac{E\epsilon_0\epsilon_r l_c \zeta}{K_i \rho g} \left(1 - \text{EXP} \left(-\frac{K_i \rho g \Phi A_c}{\eta l_c A_r} t \right) \right) \quad (\text{EQN. 2})$$

All other variables are the same as in EQN. 1.

Data obtained for a sample of clay can be seen in FIG. 5. Height changes were taken over a three-hour period with the digital camera 18 sampling at five-minute intervals. The succession of 8 bit greyscale images taken, were recorded on a PC, 19 as shown in the schematic FIG. 6. Conversion to length was made, by capturing an image of a micrometer set at 100 microns using the same camera settings and software magnifications. The light source 16, a tungsten halogen bulb illuminated the reservoir meniscus 17 to get the best definition on the digital image. The reservoirs diameters are sufficiently large that a flat region exists in the middle of the meniscus. This point was taken as the reference for the height changes.

Before measurements of porosity can be made the system has to be run with no sample NS, FIG. 5 this will give a consistent arbitrary height change for a given voltage. The system is filled from one side allowing time for the levels in both reservoirs to equalise naturally. When no more change can be seen, then the experiment can begin. Immediately on applying voltage across the electrodes a movement of the meniscus can be observed with the camera. Similarly if a sample of soil or sandstone is present a greater movement results such as S in FIG. 5.

To get a good conducting path the sample must be thoroughly pre-soaked in the polar solvent. If the sample has small pores it can be sometimes difficult to do this. The high surface tension of water can prevent permeation into narrow pores so a lower surface tension liquid such as methanol may be used to ensure thorough wetting. Using a different solvent also requires the experiment is to be run with that same solvent. Methanol has the disadvantage of being toxic and not giving so greater δL values as water.

Once both graphs S and NS have been obtained they are subtracted from one another in order to find the height change produced by the porous sample. The equation, EQN. 2 is then applied to the data. Given the sample, the intrinsic permeability can then be estimated approximately from look up tables or found by using existing British Standards techniques before calculation of the porosity.

Although the clay sample was run for three hours, as short a period as thirty minutes can give satisfactory data. The initial rise of the slope is the most important feature of the graph FIG. 5 and not the final difference in reservoir heights reached. Clay porosity is given as a percentage and was found to be about 9-15 percent by volume for several different clays.

For this apparatus to work the essential feature is the quartz capillary. This provides the surface charges and electroosmotic driving force of the system. Its diameter is critical for the height changes to be measurable. The problem with using water as a solvent for some limestones is that ionic species can become dissolved in the solvent and give irregular results.

With clay and soil samples, pieces of material can be mobilized from the sample to possibly block the quartz glass capillary - thus stopping the experiment. To overcome this, the solvent's direction of flow must always be in the AB direction as shown in

FIG. 2 and not BA. Following the AB direction through the sample holder ensures that contamination is carried away from the capillary and hence prevents blockage.

CLAIMS.

1. A porosity-measuring device provides a method of absolute measurement of porosity by an electroosmotic means.
2. The apparatus consists of two transparent vertical reservoirs, a sample holder and two electrode compartments.
3. All pieces are secured by screw threads to allow ease of storage and cleaning.
4. The sample holder is fitted with a "key" – a cylindrical tube that inserts inside the outer sample holder; thus providing a cavity through to the glass capillary, where solvent will flow.
5. Filter paper membranes in the said electrode compartments prevent migration of gas bubbles into the porosity determining area.
6. A digital camera records images of a moving column of water or other polar, electrically conducting solvent and converts them into reservoir height changes.
7. Electrodes in the said electrode compartments provide the main motive force for liquid motion.
8. Direction of solvent flow prevents blocking of the glass capillary by contaminant particles released from the sample. Thus keeping the experiment running.
9. A porosity-measuring device substantially as herein described and illustrated in the accompanying drawing(s).



INVESTOR IN PEOPLE

Application No: GB 0109234.5
Claims searched: ALL

Examiner: Michael Walker
Date of search: 22 August 2001

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G1S (SGX)

Int Cl (Ed.7): G01N 15/08

Other: On-line: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2280512 A (INSTITUT FRANCAIS-) see abstract	1,2
X	WO 96/02627 A1 (SMITHKLINE-) see abstract	1,2
X	US 5503001 (WONG) see abstract	1,2,7

X Document indicating lack of novelty or inventive step
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