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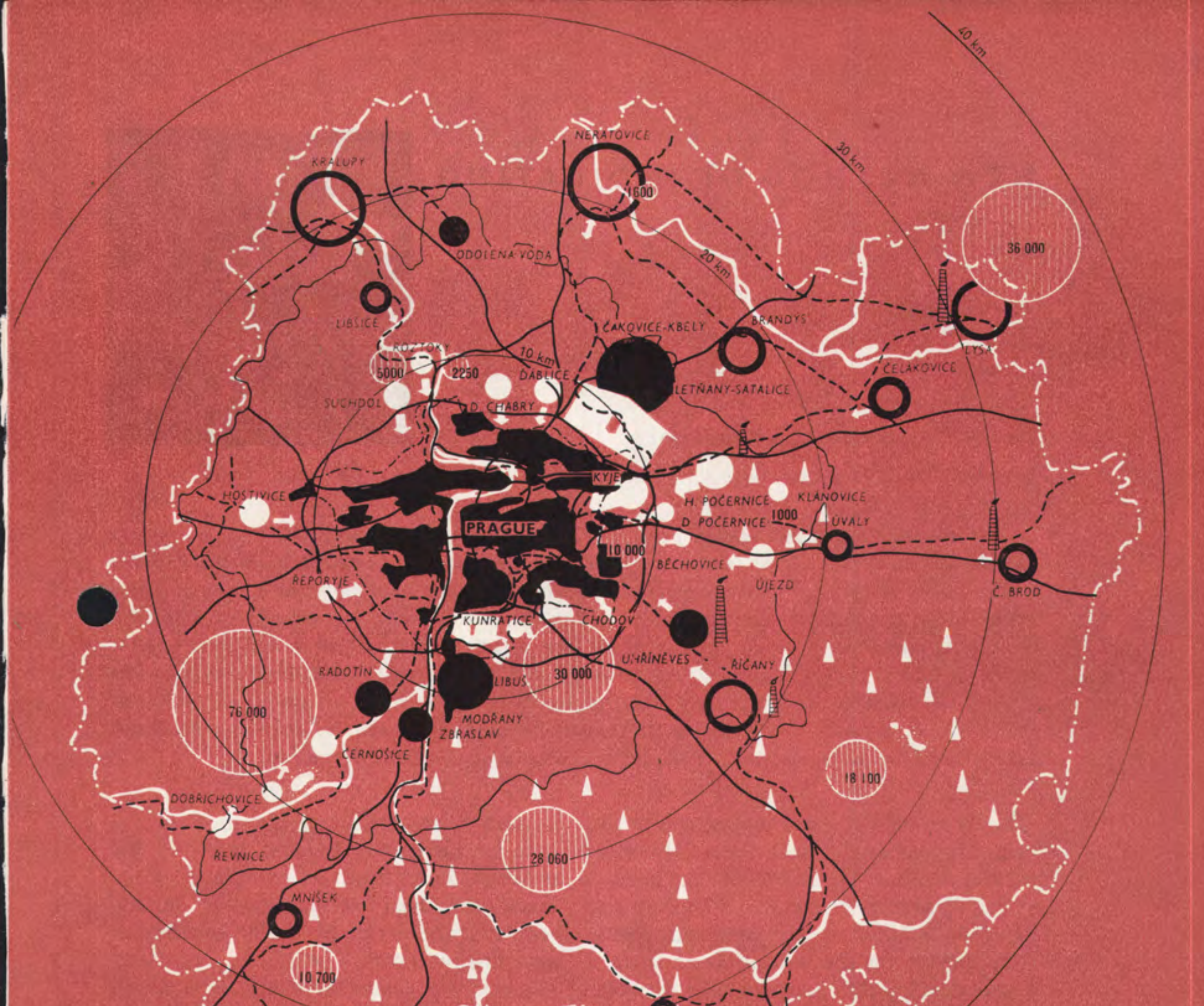

Fig. 12. *Main relations in Prague sphere of interest*

NEW METHOD OF INDICATING CRACKS IN BRITTLE MATERIALS

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The investigation of mechanical properties in building materials and structures frequently necessitates an accurate and sensitive method of determining the moment when cracks occur in the loaded sample and of locating them. Cracks of 0.2 mm minimum width (i.e. of a size visible to the unaided eye) could be determined in concrete by methods known so far. For these tests, a narrow strip of brittle conductive lacquer, approximately 30 cm in length, is applied to the surface of the specimen and forms part of an electric circuit which carries a very weak current. The resistance of the strip is in the range of one hundred to several thousands of ohms. The occurrence of a crack in the specimen breaks the conductive strip and hence the current, and indicates the crack by the sudden increase of the circuit resistance.

A new method of ascertaining cracks has been evolved at the Institute of Theoretical and Applied Mechanics of the Czechoslovak Academy of Sciences. This method, based on a different and new principle[1] is applicable for the indication of surface cracks developing under static or dynamic load, as well as for the detection of microscopic flaws on the surface of unloaded structures.

The new method employs as a component of an electric circuit a strip of conductive lacquer made from an aqueous dispersion of synthetic (e.g. polyvinyl) resin filled with powdered contact silver, iron, or other suitable conductive material. This lacquer is highly conductive—the resistance of a 30-cm strip ranges from 1 to 30 ohms—and is not brittle. The current flowing through the circuit is of relatively high intensity and the voltage—depending on the resistance of the strip—is selected so that the current reaches 2 to 15 A, in actual practice it is between 20 and 220 V according to the application. The current heats the strip, but most of the heat is dissipated by the mass of the material under test. At the place of the crack the heat conduction is greatly reduced, the strip is locally overheated and finally fuses. The current intensity required for fusing depends, in addition to the resistance of the strip, mainly on the width of the crack. The narrower the crack the higher is the intensity required.

For the indication of cracks on the surface of a loaded sample of concrete the current should be such as to heat the strip to 40–60 °C. At the fused spot the resistance of the strip increases to such an extent that the meter drops to zero, and this current drop below a measurable value is therefore the indication of the damage incurred by the test object. If the voltage of the open circuit is increased by the application of a regulation transformer or series resistor, sparking at the spot of interruption burns the lacquer (*Fig. 1*). The crack is thus not only reliably indicated but its course is permanently recorded on the strip. According to the conditions of the test, cracks of one micron width (and often even finer ones) can be reliably

(1) Czechoslovak patent application No. PV 5640–60. Applications filed in France, the German Federal Republic and Great Britain.

indicated (*Figs. 2 and 3*). If existing microscopic cracks on the surface of a concrete member have to be indicated, the intensity of the current flowing through the strip has to be continuously increased up to the moment of fusing. Provided the conductive lacquer film is of approximately uniform thickness, it fuses where cracks of at least 0.1 micron width are present (*Fig. 4*). The strip fuses at a current of 4 to 15 A, with 40 to 240 V applied, the value depending on the resistance and thickness of the film and on the width of the crack. After fusing, the sparks permanently record the course of the crack.

This method has been tried out for the indication of cracks in concrete, but is equally suitable for other brittle materials.

The instrument for crack indication at static loads consists of a current source (regulation transformer), an ammeter and a switch (*Fig. 5*); if a series resistor is used in the circuit, sparking takes place automatically as soon as the strip fuses.

For crack indication at dynamic loads the instrument consists in the main of as many counters as there are strips, of a current source and a mercury relay. A rectifier is used as source; it is powered through a transformer the primary voltage of which is controlled by the regulation transformer. The current flows into the counters through a contact operated by the coil of the relay. One terminal of this coil is connected to a source of 220 V, the other is connected to earth through the contact of the counter (*Fig. 6*). Usually the cracks need not be burned since the normal working current intensity is sufficient to produce clearly discernible traces

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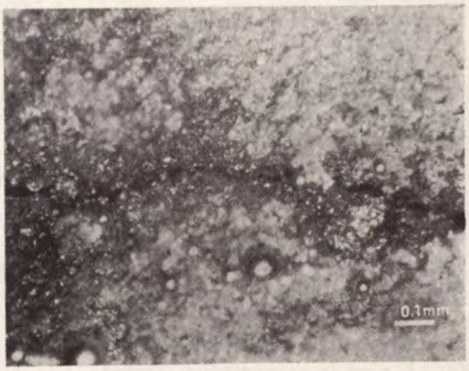

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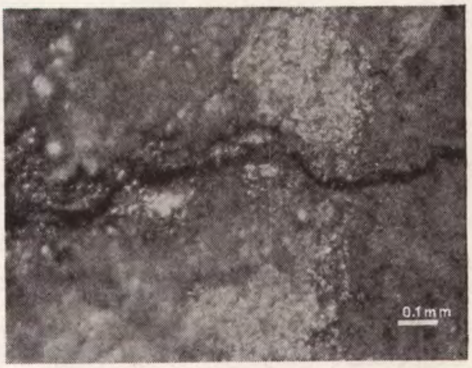

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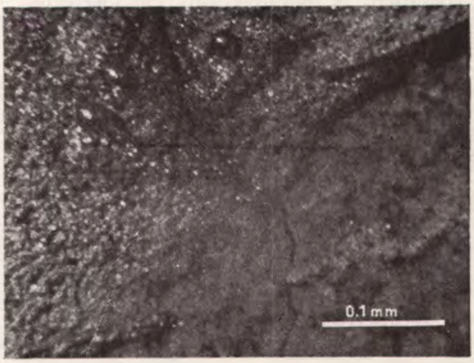

Fig. 1. *Burned lacquer at failure spot is discernable with the naked eye. (Magnified 2×.)*

Fig. 2. *Burned lacquer at the break after sparking*

Fig. 3. *Indication of 0.03-mm crack produced by loading test on a bent girder*

Fig. 4. *Indication of microscopic crack of approximately 0.003 mm width produced in concrete by shrinkage*

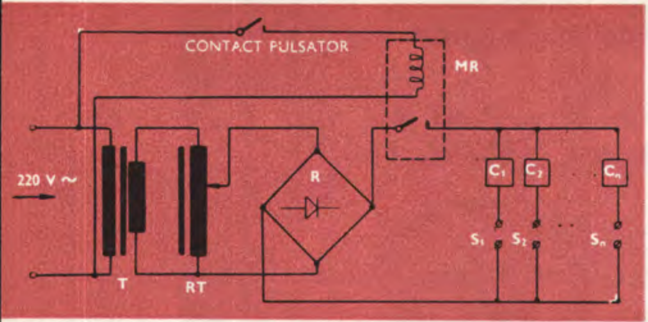

Fig. 6. *Apparatus for indicating cracks under dynamic load*

T — transformer; RT — regulation transformer; R — rectifier; MR — mercury relay; C_1, C_2, C_3 — counters; S_1, S_2, S_n — terminals for the indicating lacquer strips

owing to the alternate opening and closing of the cracks in the strips.

Before the lacquer strip is applied the surface must be cleaned and degreased. Grinding, which is liable to fill cracks with dust, must definitely be avoided if existing microscopic cracks have to be ascertained on the surface of concrete, the surface is merely cleaned and degreased.

The conductive lacquer is applied with a small brush to a width of approximately 1 cm. The length (as required) is 10 to 50 cm. The film—between 0.05 to 0.15 mm—should be of uniform thickness. After drying, the ends of the strip are tinned in order to facilitate the connection into the circuit; tin adheres well to the lacquer.

Before the actual measurement it is essential to ascertain whether at a current of 2 to 4 A flowing for a few minutes the strips are actually heated to the optimum temperature of 40 to 60°C. Then the specimen is inserted into the test equipment, the instruments are connected and the sample is gradually loaded. The individual circuits are connected successively and the optimum currents are adjusted and maintained over a period sufficient for heating the strip (usually a few seconds will suffice). As soon as the circuit is broken (indicated by the ammeter), sparking can be produced by raising the voltage, in order to record the crack on the strip. *Figs. 2 and 3* are micrographs of the border between the concrete

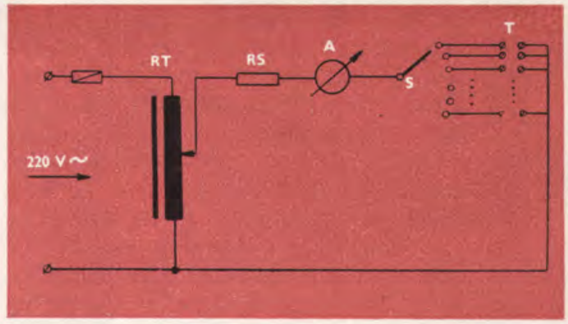

Fig. 5. *Apparatus for indicating cracks under static load*

RT – regulation transformer; Rs — series resistor; A — ammeter; S — switch; T — terminals for the indicator strips

and the indicating lacquer strip at the spot of burning.

For ascertaining microscopic cracks, the current intensity of the individual circuits is gradually increased until fusing occurs. The required intensity depends on the film thickness and the width of the crack; the finer the crack, the higher is the fusing current. As a rule, cracks wider than 0.1 mm cannot be indicated by this method as the lacquer flows into them and fills them up. The increased thickness of the film at such cracks is responsible for the fact that the strip fuses sooner over a finer crack where the film is thinner. The width of microscopic cracks indicated by this method was ascertained with a metallurgical microscope by comparing against a precisely graduated rule. Under one micron the width of cracks could not be precisely measured owing to the limited resolving power of the microscope employed.

A larger microcrack is in *Fig. 4*, its width can be estimated to 20–30 microns.

For the detection of cracks during repetitive loads the method is essentially the same as described for the static test, the difference being that the connection of the individual circuits is automatic, for instance synchronous with a certain number of cycles (e.g. 1000). The moment when the crack occurs is recorded by a counter. Sparking can be produced by increasing the voltage across the appropriate strip.