

The ultrasonic testing of concrete

Report of a meeting held at University College, London

As a result of a meeting on ultrasonic testing of concrete held at the Institution of Structural Engineers in October, 1955, Dr Jones of the Road Research Laboratory called together a meeting of those people having some direct interest in this subject to exchange information on the technique, and to discuss in more detail factors affecting the apparatus used. A summary of the main conclusions arising from the discussion, which was held at the Department of Civil and Municipal Engineering, University College, London, on 20th December, 1955, is given below.

Interference

Both electrical or mechanical (acoustic) interference may affect the apparatus: on building sites both effects are often troublesome.

The electrical problems are mainly concerned with fluctuations of the mains voltage and with mains-borne pick-up arising from the operation of machinery on the site power line: remedial measures are being tested by Mr A. E. Cawkell, the present manufacturer of the apparatus. Experiments are in hand to devise a suitable filter to cut off frequencies lower than about 10 kc/s, with a view to reducing the interference caused by mechanical vibrations from plant on building sites. Valves of shock-tested quality are being used to reduce replacement and to cut down microphony. Most users agree, however, that microphony is not often troublesome.

Coupling

The choice of coupling medium used between the transducer face and the concrete surface generally depends on the particular circumstances. Oily or greasy couplants cannot always be used as it is often necessary to avoid staining the concrete surfaces. On smooth or moulded surfaces, soap jelly and bentonite paste have both proved satisfactory; for rough surfaces it is often necessary to

prepare the surface either by grinding it smooth or by applying a thin layer of plaster. Recently, however, a kaolin-glycerol paste has been found to give adequate coupling to rough surfaces such as are given by a trowelled finish. In all cases the layer of couplant should be as thin as possible, as otherwise there will be an error in the measurements.

Path-length measurement

It was generally agreed that on site work an accurate measurement of the path length between the transducers is often impossible with existing equipment. It was suggested that auxiliary equipment is needed to measure path length more accurately by other means. An alternative to the transmission technique is to produce a pulse which travels parallel to one surface and to measure the pulse velocity along this surface. In France, a mechanical hammer pulse technique is used in this way.

Number of measurements required

No simple guide can be suggested for the number of measurements to be made either for in situ work or for laboratory specimens. For ultrasonic exploration, grids of 6 to 8 in. have been used frequently, but 3 in. grids are often required for more detailed surveys. The smaller grids are particularly required where large local variations occur, such as a large variation of composition at different heights in a lift. It was suggested that measurements on cubes should be made at the top, centre and bottom for one pair of faces when carrying out calibration tests, but no standard procedure has been adopted by different users.

Standard testpieces

It is not considered necessary to draw up a standard specification for a calibrating testpiece of some suitable metal. It was suggested that confidence in the accuracy of the time measurements is ensured by the frequency-

check crystal incorporated in the instrument, and any testpiece should take the form of a single testpiece which could be passed round to different users of the apparatus.

Interpretation of ultrasonic measurements

Many difficulties present themselves when attempts are made to estimate strength from velocity measurements. Apart from the difficulties due to differences in mix proportions and type of aggregate, which are well known, a number of new factors have recently come to light. It has been noticed that the pulse velocity along the length of a concrete beam is generally about 5% lower than the velocity across the beam. Recent experiments in France suggested that this is due mainly to anisotropy of the concrete in the beams, and measurements made after the beams have been sawn into portions confirmed that the same differences of velocity are obtained independently of path length. Anisotropic effects have been noticed by the Mono Concrete Co. during ultrasonic tests on pre-cast units.

One of the most important problems in connexion with interpretation concerns the curing of the concrete. Work at Queen Mary College has shown that the rate of curing has a considerable effect on the strength-velocity relation, such that estimates of strength based on calibration curves, obtained at normal temperatures, are quite useless for, say, steam-cured concrete. It has also been noticed, independently, that low-temperature curing (i.e. just above 32°F) produces a similar effect. When measuring changes in laboratory-cured specimens under controlled conditions, these effects are not serious. In many cases of testing concrete on the site, however, the effect might invalidate estimates of strength. Where possible a separate batch of test cubes cured under the site conditions might prove helpful.

One source of difficulty is due to the discrepancy which often occurs between the pulse velocity in the structural concrete and the comparable test cube at the same age. The pulse velocity in the structure is usually lower than that in the test cube, and the problem is to interpret the discrepancy as a reduction in strength.

Some doubt was expressed regarding the strength-velocity relation being given by a single curve for a given aggregate and mix proportions, since the manner of varying the strength (i.e. by varying the water/cement ratio or the age) would have an effect on the relation. It was suggested that velocities at an early age are not a guide to strengths at later ages. This is unfortunate

since, in practice, faults detected at an early age can be rectified more easily than faults detected later.

Recent work by the Cement and Concrete Association suggests that, for site control work, the most useful curves relating strength and velocity are those plotted on a basis of constant workability, rather than of constant proportions. In field work, workability is more likely to remain constant than are the mix proportions, and tests have shown that constant workability for given curing conditions and given aggregate provide a reliable calibration for pulse-velocity and strength.

It was emphasized that the method is essentially one of comparison and, both in structures and laboratory specimens, velocity measurements can reliably check variation of quality. The Cement and Concrete Association has used a comparison technique for assessing the relative quality of work that is nominally identical or of structural members from which test cubes have given diverse results. Work by the Building Research Station has shown that the technique can be used to detect voids requiring grouting and to check the effectiveness of the grouting.

It was considered that insufficient work on the effect of compaction had been done, and this effect might usefully be studied further.

Localized weaknesses, such as a simple crack or a small cavity in the path of the pulse, do not necessarily cause a significant decrease in the pulse velocity. However, there is usually a large decrease in the amplitude of the received signal.

Additional measurements of the attenuation of the pulse might help in the interpretation of the results. The main difficulty of such a method is that part of the total attenuation occurs at the contact surfaces between the concrete and the transducer, and this is difficult to measure separately. However, it was reported that Bradfield has recently patented a device which enables the amplitude of the pulse entering the material to be monitored by means of an auxiliary crystal pick-up on the transmitting transducer. This pick-up enables measurements to be made of the amplitude of the part of the pulse reflected from the contact surface. A similar procedure would be required to allow for attenuation at the receiving transducer by a duplicate auxiliary pick-up device.

The meeting generally agreed that the ultrasonic pulse method should not yet be considered for adoption as a British Standard test.